Amphibian and Reptile Conservation

RESEARCH REPORT 18/01

Jersey multi-species distribution, habitat suitability & connectivity modelling

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ARC Science Team

States of Jersey

amphibian and reptile conservation

Acknowledgements

We are grateful for the cooperation of the Jersey Biodiversity Centre, Tim Ransom, the Société Jersiaise and its various botanical, zoological and mycological sections, and all others that provided data for this study. This includes all of those who have contributed records over the years to provide sufficient data for this project. Natural Environment, Growth, Housing and Environment, States of Jersey, provided mapping data, support and valuable comments on the report. We also wish to thank the varied landowners, land managers, policy makers and species experts who participated in workshops and provided valuable insights and constructive feedback to the development of this project.

SUGGESTED CITATION: Ward, R.J. and Wilkinson, J.W. (2018) Jersey multi-species distribution, habitat suitability and connectivity modelling. ARC Research Report 18/01.

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Tables and Figures

Additional documentation

Additional documentation is supplied in the following forms to support this report:

- Appendix A – A breakdown of landcover definitions used in previous reports, relevant to this study
- Appendix B – A review of the ecology and conservation status of our focal study species, and of the movement and dispersal capabilities of Jersey's protected species.
- Appendix C – Detailed supplementary methods
- Appendix D – MaxEnt species distribution modelling outputs including model performance evaluation and species-specific response variables
- Appendix E – Additional results supporting the evaluation of Habitat Concentration Areas
- Appendix F – Species-specific least-cost path and least-cost corridor maps
- Appendix G – Outputs related to the prioritisation of Habitat Concentration Areas for protection and management based on their contribution to connectivity
- File index – Excel spreadsheet containing descriptions and file paths of important Geographic Information Systems (GIS) and analysis files

Study aims

The States of Jersey are signatories to a number of multilateral environmental agreements (MEAs), and as such, are obliged to protect and conserve local biodiversity. Jersey hosts a diversity of wildlife which occurs across the island and within a network of sites subject to varying degrees of statutory protection. This report seeks to identify the suitability of this terrestrial ecological network and makes suggestions for improvement using modelling approaches with the following steps:

A. Identify which features in the landscape (e.g. habitat types) are important to the survival of a variety of terrestrial species selected to meet set criteria, including those protected under the Conservation of Wildlife (Jersey) Law 2000 / Conservation of Wildlife (Protected Plants) (Jersey) Order 2009, as a representation of the wider needs of Jersey's wildlife.

B. Select priority conservation areas for Jersey's terrestrial protected species, assess the suitability of Jersey's current protected area network for meeting these needs and make recommendations for improvements.

C. Assess connectivity between these priority areas to define optimal routes where habitat protection and management can assist wildlife in their movements through the landscape.

D. Prioritise the selection of areas for protection and / or management actions based on conservation value and return on investment.

E. Where appropriate, account for the influence of the urban environment by carrying out the analyses above (aims B–D) separately for species associated with non-urban and urban areas.

To meet these aims we provide the following key outputs:

A. An assessment of the variables influencing the distributions of multiple species.

B. Individual and combined species distribution maps, highlighting areas where high suitability for multiple species overlap.
    a. An evaluation of how these areas overlap with existing statutory designations.

C. Maps identifying least-cost paths and corridors between areas of high suitability for individual and combined study species.

D. A set of areas prioritised for wildlife conservation based on their contribution to connectivity, current designation and return on investment.

E. Outputs B–D with separate consideration of:
    a. all focal study species
    b. only species without associations to built-up areas
    c. only species with associations to built-up areas

F. GIS files for use by the States of Jersey to allow:
    a. use within internal GIS applications, and
    b. future replicate studies to be conducted with the same dataset.

We also review the current status of Jersey's natural environment.

Background

Purpose Statement

The States of Jersey has a moral and legal duty to conserve its natural heritage. One of the biggest threats to Jersey's wildlife is a fragmented and changing landscape. A number of species already receive protection under the Conservation of Wildlife (Jersey) Law 2000 and Conservation of Wildlife (Protected Plants) (Jersey) Order 2009. Identifying priority areas for these protected species can inform decisions on spatial planning, protection and management. Ultimately, a well-connected network of important habitats will benefit Jersey's wildlife. This project contributes to the implementation of Jersey's policy requirements under the Revised 2011 Island Plan (specifically Policy NE 1,2,3,4 and 6) and Jersey's draft Protected Areas Strategy aiming to define the locations and quantity of land which we need to protect for wildlife.

Previous modelling work has predicted the distribution of toads (*Bufo spinosus*) (Wilkinson and Starnes 2016) and grass snakes (*Natrix helvetica*) (Ward 2017) in Jersey and has highlighted connectivity issues between subpopulations in the island. The present work expands on these approaches by incorporating a wide range of species of varying forms, ecological roles, traits and conservation status in order to inform an island-wide plan for maintaining, improving, designating and connecting wildlife areas. Furthermore, it highlights areas where improvements to connectivity are most beneficial, and how these may be tied in with other efforts in parallel for maximum return on investment.

The robust methods applied in this work support the decision-making processes within Natural Environment, Growth, Housing and Environment, States of Jersey, with implications for wildlife conservation, planning and building. We set out to identify key areas of conservation priority for a selection of threatened species based on their distribution, importance for connectivity and current protection status, whilst considering the areas providing the most overall benefit. Furthermore, we identify the driving factors influencing the suitability of Jersey's semi-natural landscape for those species.

Habitat loss and fragmentation

Human influence and modification of the landscape often results in historically continuous swathes of habitat becoming broken up in to smaller, more isolated patches with an overall reduced extent. Such changes can occur at a variety of spatial scales and may be driven by the need for transport infrastructure, housing, other forms of development and agriculture. The variety of wildlife (known as biodiversity) present is often negatively affected by these changes due to one or a combination of several factors including (i) reduced population size, (ii) increased risk of mortality (e.g. roadkill), (iii) reduced dispersal ability and (iv) a lack of natural resources to support a population. There is a threshold below which a population of a species is no longer functional, whereby it is unable to maintain a long-term population and ultimately, will go extinct. The presence of routes through which wildlife can move to disperse, gain access to resources, migrate and found new populations is of utmost importance to a population's survival. This connectivity is also essential to ensure species can shift their ranges to counteract the effects of climate change; though such range-shift opportunities are limited in an island the size of Jersey.

Jersey

Isolated from France by over 20 km of open water, the 120 km^2 island of Jersey has a unique ecosystem with outside influences stemming only from migratory and wind-borne species, or those introduced by humans. It has a resident population of over 105,500 people (Statistics Jersey 2018) plus an active throughput of tourists. With this high population density comes associated development, infrastructure and agriculture. Despite this, much of the island can be considered rural in a landscape context, with dominant structural features consisting of linear hedgerows, banks and treelines amongst a matrix of fields.

Biodiversity

The Channel Islands contain a unique selection of wildlife, with each island differing from the others in terms of their ecological community owing to geological differences and the influences of their human inhabitants. Indeed, Jersey's approximate 7,000-year isolation (Johnston 1981; Jones 1993) has yielded a unique lineage of bank vole (*Myodes glareolus caesarius*). Declines and losses of both habitats and species have been documented, with examples including reductions in forest cover (Gurnell et al. 2002), the decline (and subsequent recovery) of the agile frog (*Rana dalmatina*) (Ward et al. 2016) and the apparent loss of the stoat (*Mustela erminea*) (Magris and Gurnell 2000; Mcgowan and Gurnell 2014). The island contains no large mammals, with the largest non-domestic mammals remaining being the result of species introductions, now treated as natives. These include the red squirrel (*Sciurus vulgaris*), the hedgehog (*Erinaceus europaeus*) and the rabbit (*Oryctolagus cuniculus*) (Le Sueur 1976). In contrast, a variety of other introduced non-native species are potential sources of risk to Jersey's biodiversity and are the target of control and removal efforts, such as the succulent plant hottentot fig (*Carpobrotus edulis*).

There are approximately 8,950 species currently known in Jersey and its waters (Table 1) (Jersey Biodiversity Centre personal communication), including regular migrants and vagrants (e.g. Young et al. 2016). Undoubtedly, this is an underestimation, as some of these groups such as invertebrates are understudied. A number of these species are conservation priorities both in Jersey and abroad (e.g. Table 5), with 49 Biodiversity Action Plans currently drawn up for Jersey's species and a further three for habitats.

Conservation issues

The issues facing Jersey's biodiversity reflect those found across much of Europe and beyond. Namely, conversion of the landscape leading to high levels of fragmentation, edge effects, and associated habitat loss; with little semi-natural habitat remaining. Those areas that do remain are primarily restricted to the north, east and west coastal regions in addition to a handful of wooded valleys in the island's interior; though many of these areas are degraded and dominated by bracken. Further pressures are brought about from the high human population density which swells with tourism, and the associated threats brought by man including non-native species (e.g. pheasants and polecats) and agricultural and vehicular sources of pollution.

Table 1 A summary of Jersey's biodiversity, showing the number of species known in Jersey and its waters (including non-natives).

Group	No. species	Source*
Animals		
Amphibians	3	JARG / JBC
Birds	331	(Young et al. 2016)
Fish		
Ray-finned fish (Actinopterygii)	118	JBC
Cartilaginous fish (Chondrichthyes)	21	JBC
Jawless fish (Agnatha)	2	JBC
Lancelet (Cephalochordata)	1	JBC
Tunicate (Urochordata)	35	JBC
Mammals		
Terrestrial	33	JBC
Marine	13	JBC
Reptiles	8	JARG / JBC
Invertebrates		
Worms (Annelids)	111	JBC
Peanut worms (Sipuncula)	4	JBC
Arthropods		
Arachnids		
Mites & ticks (Acari)	81	JBC
False scorpions (Psuedoscorpiones)	1	JBC
Harvestman (Opiliones)	12	JBC
Spiders (Araneae)	208	JBC
Insects	3384	JBC
Centipedes	17	JBC
Millipedes	19	JBC
Crustaceans	395	JBC
Springtails	35	JBC
Sea spider (Pycnogonida)	9	JBC
Bryozoan	64	JBC
Cnidaria	51	JBC
Comb jelly (Ctenophora)	1	JBC
Echinoderm	30	JBC

Table 1 continued

Group	No. species	Source*
Entoprocta	4	JBC
Arrow worm (Chaetognatha)	2	JBC
Acorn worm (Hemichordata)	2	JBC
Roundworm (Nematoda)	1	JBC
Ribbon worm (Nemertea)	8	JBC
Flatworm (Turbellaria)	12	JBC
Molluscs	438	JBC
Sponge (Porifera)	52	JBC
Priapulid	1	JBC
Waterbear (Tardigrada)	11	JBC
Plants		
Flowering plants	1238	JBC
Ferns	32	JBC
Conifers	21	JBC
Moss	258	JBC
Clubmoss (Isoetopsida)	1	JBC
Hornwort	2	JBC
Stonewort	7	JBC
Horsetail	5	JBC
Liverwort	80	JBC
Alga	258	JBC
Fungi	1007	JBC
Lichen	402	JBC
Slime mould	12	JBC
Chromist	93	JBC
Oomyctes	9	JBC
Bacteria	15	JBC

* JBC: Jersey Biodiversity Centre; JARG: Jersey Amphibian and Reptile Group

Values are accurate as of July 2018

Species protection

Many animal species in Jersey are offered protection under the Conservation of Wildlife (Jersey) Law 2000 (see https://www.jerseylaw.je/laws/revised/Pages/22.450.aspx); referred to from hereon as **CWL 2000**. These protections fall under four schedules;

1. Protected wild animals and protected wild birds
2. Specially protected wild birds
3. Animals which may not be killed or taken by certain methods
4. Reptiles and amphibians which may not be exported.

A number of plant species are also afforded protection under the Conservation of Wildlife (Protected Plants) (Jersey) Order 2009 (see https://www.jerseylaw.je/laws/revised/pages/22.450.70.aspx); referred to from hereon as **CWL 2009**. Throughout this document, general references to species protection in Jersey are simply referred to as **CWL**. Terrestrial invertebrates, fungi and lichen currently receive no protection. However, a recent Quinquennial review[1] of CWL schedules will lead to some of their protection under a newly drafted CWL proposed to be adopted in 2019, as well as potential changes in the protected status of some plants and vertebrates.

Efforts to ensure favourable status for Jersey's habitats and species are also guided by the Biodiversity Strategy (Planning and Environment Committee 2002). In addition, the States of Jersey is a signatory to several multilateral environmental agreements (MEAs) (Table 2) including the Convention on Biological Diversity, the Bern Convention on the Conservation of European Wildlife and Natural Habitats, the EC Habitats and Species Directive and the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals). These agreements not only require Jersey to report on the status of its biodiversity, but some also require additional species protection. These protections require due diligence from both the States of Jersey and developers in order to meet their responsibilities to the island's natural environment.

Because of the protected status of many of Jersey's species, developers have a legal obligation to ensure appropriate surveys are carried out by ecological consultants to determine if such species are present, and to subsequently undertake appropriate measures to mitigate

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[1] A consultation on a new draft wildlife law was being undertaken during the writing of this report. Therefore, references to wildlife conservation laws and protected species schedules reflect those available at the time of writing (true as of July 2018), and may differ from those in place at the time of reading.

for the effects of the development upon protected flora and fauna. The data resulting from surveys conducted by ecological consultants in addition to citizen scientists and other local wildlife recorders is stored by the Jersey Biodiversity Centre (JBC). As such, it can be used for informing future planning applications and studies of individual species. In this study, we make use of occurrence data for multiple species to produce maps of habitat suitability for a variety of focal species. These maps are then of use to Natural Environment, Growth, Housing and Environment by highlighting areas of sensitivity where species records may be absent and thus directing appropriate measures for developers to undertake (i.e. by informing which protected species may be present).

Island Planning

Decision making processes related to planning in Jersey are directed by the Revised 2011 Island Plan (States of Jersey 2014). This essential piece of documentation is responsible for guiding and controlling development, and is supported by the Planning and Building (Jersey) Law 2002. Included within the strategic principles of the Island Plan is protection of the environment; both natural and historic (Policy SP 4). This is supported by multiple policies, objectives, indicators and proposals including:

- Policies
    - GD 1: General development considerations
    - NE 1: Conservation and enhancement of biological diversity
    - NE 2: Species protection
    - NE 3: Wildlife corridors
    - NE 4: Trees, woodland and boundary features
    - NE 6: Coastal National Park
    - NE 7: Green Zone
    - NE 8: Access and awareness
- Objectives
    - NE 1: Natural environment objectives
- Indicators
    - NE 1: Natural environment indicators
- Proposals
    - 4: Wildlife corridors
    - 5: Coast and countryside character
    - 6: Restrict permitted development rights in the Coastal National Park
- Proposal 7: Coastal National Park Management Plan

- Proposal 8: Landscape Management Strategy

Certain aspects of the landscape have been previously defined as Character Areas in the Countryside Character Appraisal (States of Jersey Planning and Environment Committee 1999). There is a general presumption against development in these areas, and we refer to them in the text as CAs (identified in red) when describing certain components of the landscape.

Connecting wildlife

In order to be effective in any efforts to maintain the island's species diversity, a critical step is understanding how species are distributed within the landscape, and to what extent their populations are connected or isolated. This allows for the appropriate management of sites of importance to biodiversity, the selection of new sites deserving of management, and avenues by which work should be carried out to enable movement of individuals between subpopulations and to new suitable areas on the island. Employing a desk-based modelling approach makes the most of available data within the JBC and enables different conservation strategies to be evaluated at low cost.

To achieve our aims, we make use of several modelling approaches. The first of these is species distribution modelling (sometimes also referred to as habitat suitability modelling). This approach uses data on the occurrence of a species and geographical layers presumed to have an influence on the species' distribution to make predictions of suitability for that species over a landscape of interest. Another method used in this report is to identify the most likely corridors (routes) through which wildlife may move, with the expectation that they will use the route which takes the least amount of effort (or 'cost'). This approach takes information on the areas to connect, and the resistance of the landscape the species is trying to move through. For instance, roads may be expected to have a high resistance for movement of many species due to wildlife being exposed to predators and traffic whilst traversing across them. In contrast, intact areas of natural habitat suited to the species are likely to have very low resistance for movements. Further detail on these methods is given in Appendix C.

Previous studies of habitat use and connectivity have often focused on single species and/or those with large dispersal capabilities such as many mammals (Brodie et al. 2015; Correa Ayram et al. 2016; Ziółkowska et al. 2016; DeMatteo et al. 2017). This often relies on the assumption of 'umbrella species' being representative of the needs of others; but this assumption is not always appropriate (Andelman and Fagan 2000). Furthermore, the biodiversity remaining within Jersey does not contain any large mammals, instead being dominated by small terrestrial vertebrates, invertebrates, birds, bats, plants and fungi. Many of these are restricted in their distribution, with few or single known localities and suspected small population sizes. In addition, many of the island's species receive partial or full protection under the CWL and are listed under other conservation statutes. In this report, we attempt to evaluate the consequences of fragmentation upon a range of taxa on the island, quantify the efficacy of the existing protected areas network and identify the most cost-effective routes through which functional connectivity should be maintained and improved.

Though single-species approaches to identifying conservation priorities, species distributions, habitat suitability and connectivity have been undertaken in Jersey before (e.g. Wilkinson and Starnes 2016; Ward 2017), their findings may not reflect the needs of a wider variety of species. This study heeds the calls of previous projects for an evaluation of habitat availability, suitability and connectivity for multiple species in Jersey (Mcgowan and Gurnell 2014; Ward 2017); thereby providing a solid foundation for an island-wide conservation strategy of practical value.

This study utilises presence data from 17 species resident within Jersey, representing a range of life histories, dispersal capabilities, abundances, distributions and conservation needs. These are drawn from the major groups of terrestrial organisms found within the island; mammals, reptiles, amphibians, invertebrates, plants and fungi. Specifically, this study evaluates the distribution and potential drivers of those distributions for each species, identifies biodiversity hotspots within the island, and uses connectivity analyses to infer the least costly routes through which organisms can disperse. We provide a set of priorities for future conservation to facilitate improvements to Jersey's ecological network.

Materials and Methods

N.B. *Greater detail of the steps undertaken are given in Appendix C.*

Software and Data

This study utilised the following software:

- MaxEnt v3.4.1 (Phillips et al. 2018) for species distribution modelling
- ENMTools v1.4.4 (Warren et al. 2010) for assessing correlations between predictor variables
- The freeware known as 'R' v.3.4.4 (R Core Team 2018) for data visualisation and statistical analyses
- ArcGIS Pro v.2.0.1. (ESRI 2017a) for compiling, editing and visualising maps
- ArcMap and ArcCatalog v.10.5.1 (ESRI 2017b) for conducting connectivity analyses
- Linkage Mapper v.1.1.1 (McRae and Kavanagh 2011) for conducting connectivity analyses
- Conefor v.2.6 (Saura and Torné 2009) for prioritising landscape components for protection

Most occurrence data were provided by the JBC (www.JerseyBiodiversityCentre.org.Je), with additional data provided by the Société Jersiaise Botany Section for plants and Jersey Bat Group for bats. Landcover data for Jersey were provided by Natural Environment, Growth, Housing and Environment, States of Jersey, and additional layers were downloaded from WorldClim (Fick and Hijmans 2017).

Study Area

This project focused solely on the terrestrial surface of Jersey above mean high water, excluding tidal regions to leave approximately 120 km^2 land area. The following contents of this report refer only to this terrestrial portion of Jersey.

Habitats

Habitats in Jersey have been defined in previous reports (see Appendix A); however, these definitions have been dependent on the aims of the respective report. For instance, the Biodiversity Strategy (Planning and Environment Committee 2002) lists key habitats considered as having international importance, local importance and those that are human-modified. In comparison, in order to define environmentally sensitive areas for protection, Penny Anderson Associates (PAA) (2010) produced a list of 26 classes containing 12 Key

Habitat Area types. A comparable land cover map derived from satellite data in the UK by the Centre for Ecology and Hydrology (CEH 2017) lists 21 habitat classes which uses definitions from the JNCC Biodiversity Action Plan Broad Habitat classifications (Jackson 2000).

Four key habitats types of international importance were identified in the island's Biodiversity Strategy (Planning and Environment Committee 2002): (i) coastal heathland and cliff slopes, (ii) sand dune, (iii) intertidal and (iv) marine. The first two are of relevance to this report. Four further key habitats that were listed as being locally valuable were (i) woodland, (ii) wet meadows, (iii) marsh and fresh water and (iv) boundary features. Unlike these semi-natural habitats, the island's biodiversity also occurs within two human-modified habitats which are dominant features of the landscape: (i) urban areas and (ii) farmland. Approximately 13% (1,563 ha) of the island is regarded as being built-up (urbanised) and 54% is used for farming (Planning and Environment Committee 2002). The status and conservation value of some of these habitats are discussed below.

Jersey's heathland, scrub and bracken habitats are predominantly coastal. They provide valuable habitats for wood mice, shrews, bank voles (Mcgowan and Gurnell 2014) as well as reptiles (e.g. Ward 2017), invertebrates, birds and a wide variety of plant species. Historically harvested for a variety of uses, their extent is now governed by grazing from rabbits and habitat management. Gorse scrub (*Ulex* spp.) and bracken (*Pteridium* spp.) can encroach upon and dominate other habitats including heathland, so must be managed appropriately. Additional threats include fire and agricultural expansion. Other coastal areas, particularly in the west, south-west and south-east host calcareous sand dune systems, though many of these have become stabilised due to the installation of coastal defences, or have been diminished due to developments. The dunes contain great floral diversity (Planning and Environment Committee 2002), and are an important habitat for shrews and wood mice (Mcgowan and Gurnell 2014), fungi, reptiles and invertebrates. These systems are now largely protected as SSIs, with Les Blanches Banques constituting one of the largest intact areas of semi-natural habitat in the island.

Woodlands were historically continuous (Lyte 1808; Plees 1817; Planning and Environment Committee 2002) but now cover an area of approximately 540 ha and are heavily fragmented (Magris and Gurnell 2002). These primarily occur within steep-sided valleys running north to south. Dominant tree species are sycamore (*Acer pseudoplatanus*), pedunculate oak (*Quercus robur*) and sweet chestnut (*Castanea sativa*) (Magris and Gurnell 2002). Woodland is an important habitat for Jersey's red squirrel population (Magris 1998) as well as wood mice (Mcgowan and Gurnell 2014), bats and birds. Jersey has around 1,400 km of hedgerows and other forms of boundary features, with hedgerow planting efforts between 1999 and 2002

(Magris and Gurnell 2002), and further efforts since. These provide dispersal corridors, commuting habitats and shelter for small mammals, bats and birds, and may alleviate some of the issues associated to the fragmentation of woodland.

Jersey's wetlands are either unnatural human constructions (e.g. reservoirs, garden ponds) or have been negatively affected by development, pollution, water extraction or improper management (e.g. Gibson and Freeman 1997). A handful of semi-natural wetlands remain, including La Mare au Seigneur and Grouville Marsh. These provide important habitats for a variety of birds, invertebrates, amphibians and plants. Grassland occurs in many forms across the island; though much is degraded due to agricultural improvements, grazing regimes and its use for recreation and leisure. Undisturbed grassland is an important habitat for shrews and wood mice (Mcgowan and Gurnell 2014) as well as a variety of other species including orchids.

Urban areas, though sometimes appearing devoid of wildlife, can be a haven for species that are able to utilise small patches of habitat or benefit from human refuse. Isolated pockets of habitat can occur in gardens, parks and cemeteries if properly managed. The toad is one such example, where garden ponds constitute a large proportion of its known habitat in Jersey (Wilkinson and Starnes 2016). The dominance of the farming industry in Jersey means that the way in which it is managed by those that own and farm the land has a strong influence on the local wildlife. Field margins and hedgerows are obviously potentially beneficial habitats, and recent efforts to provide rotations of winter seed crops for birds have been successful. Forthcoming changes to agricultural policy may hold further benefits for wildlife, and are discussed in greater detail later on.

Protected areas, policy and planning

The statutory protection of land and species in Jersey is governed by a number of policies (Table 2), and is the responsibility of Natural Environment, Growth, Housing and Environment, States of Jersey. Those policies that confer protection upon areas of Jersey's terrestrial surface limit the potential for developing the land in ways which negatively affect biodiversity, in areas where the natural environment is of high importance and sensitivity, and also where the character of the landscape is in need of protection. The highest tier of protection a site can be afforded is to be a Site of Special Interest (SSI). These can be designated on geological or ecological grounds; the latter of which is of most interest in this report. There are currently 21 ecological SSIs, a further nine proposed and 22 geological SSIs; some of which overlap with the ecological SSIs. Elements of Jersey's landscape are also protected as part of the Jersey National Park (JNP) and to a lesser extent, within the Green Zone, by Jersey development control policies. In comparison, landscape classifications such as Environmentally Sensitive Areas (ESAs) (Penny Anderson Associates 2010) and proposed SSIs have no legal or policy protections, but their recognition may aid their conservation (Tables 3–4; Figure 1). From here on, any reference to the Jersey National Park refers only to the portion of the JNP occurring within the Study Area defined above (i.e. within the terrestrial extent of the island of Jersey) (Figure 1). We also define a new classification for the purposes of discussion, referred to as Local Wildlife Sites. These are areas of land that we consider to be of value to wildlife but that do not receive any formal status (e.g. non-SSI nature reserves).

Table 2 Documents and conventions relevant to the protection of species and environmentally sensitive areas in Jersey.

Scale	Document / Convention
Local	Revised Island Plan 2011
	Conservation of Wildlife (Jersey) Law 2000
	Conservation of Wildlife (Protected Plants) (Jersey) Order 2009
	Biodiversity Strategy
	Species Action Plans
	SSI Designations
	Planning and Building (Jersey) Law 2002
	Agricultural Land (Control of Sales and Leases) (Jersey) Law 1974
International	Convention on Biological Diversity
	Bern Convention - The Convention on the Conservation of European Wildlife and Natural Habitats
	Bonn Convention - The Convention on the Conservation of Migratory Species of Wild Animals
	Ramsar Convention - The Convention on Wetlands of International Importance especially as Waterfowl Habitat
	CITES
	EC Birds Directive
	EC Habitats and Species Directive
	EUROBATS

Table 3 Protected area and site designations in Jersey.

Designation	Site / Area
Ecological SSI*	South Hill
	Le Petit Pré
	Noirmont
	Portelet
	La Mare au Seigneur (St Ouen's Pond)
	Noirmont Field 684
	Noirmont Field 685 and 683
	La Mare au Seigneur (St Ouen) Coastal Strip 3
	La Mare au Seigneur (St Ouen) Coastal Strip 2
	La Mare au Seigneur (St Ouen) Coastal Strip 1
	Ouaisné
	Les Landes de l'Est
	La Lande du L'Ouest (Gorselands)
	Les Blanches Banques
	Rue des Prés
	Grouville Marsh
	Bouley Bay and Les Hurets (three areas)
	Mont Orgueil
	St Ouen's Bay Coastal Strip (fields SO 1316, 1317, 1318, 1320 and 1321) North of La Route des Laveurs, St. Ouen. (La Saline)
proposed Ecological SSI*	L'Etaquerel Fort
	St Peter's Valley
	Egypte
	St Catherine's Valley Wood
	St Ouen's Bay Coastal Strip - South of El Tico
	St Ouen's Bay Coastal Strip - North of Le Braye
	St Aubin's Fort
	Fort Leicester
	La Crête Fort
Geological SSI*	Le Pinacle
	La Cotte a la Chevre
	La Cotte de St. Brelade

Table 3 continued

Designation	Site / Area
	South Hill
	La Solitude East
	La Solitude West
	Mont Huelin Quarry
	Portelet Bay
	Les Rouaux
	Giffard Bay
	Anne Port Bay
	L'Islet
	Belcroute
	Green Island
	Bouley Bay and Les Hurets (three areas)
	Le Tete des Houges
	Belle Houge Caves
	Sorel Point
	Ile Agois
	Le Grand Etacquerel
	Le Petit Etacquerel
	Le Pulec
Environmentally Sensitive Areas (ESA)	Rozel
	Grouville
	St Ouen's Bay
	South West Coast
	Noirmont - Portelet
	South-east Grasslands
	North Coast
	Les Landes
	Wooded Valleys
	St Aubin's Valley
	Beau Mont
	St. Peter's Valley Complex
	Waterworks Valley
	Waterworks Valley Link

Table 3 continued

Designation	Site / Area
	Bellozanne Valley (Vallée de Bellozanne)
	La Vallée des Vaux
	Les Grands Vaux
	Queen's Valley
Jersey National Park	
Green Zone	

* Further details on natural sites can be found on the States of Jersey's online information and public services website: https://www.gov.je/citizen/planning/pages/NaturalSites.aspx.

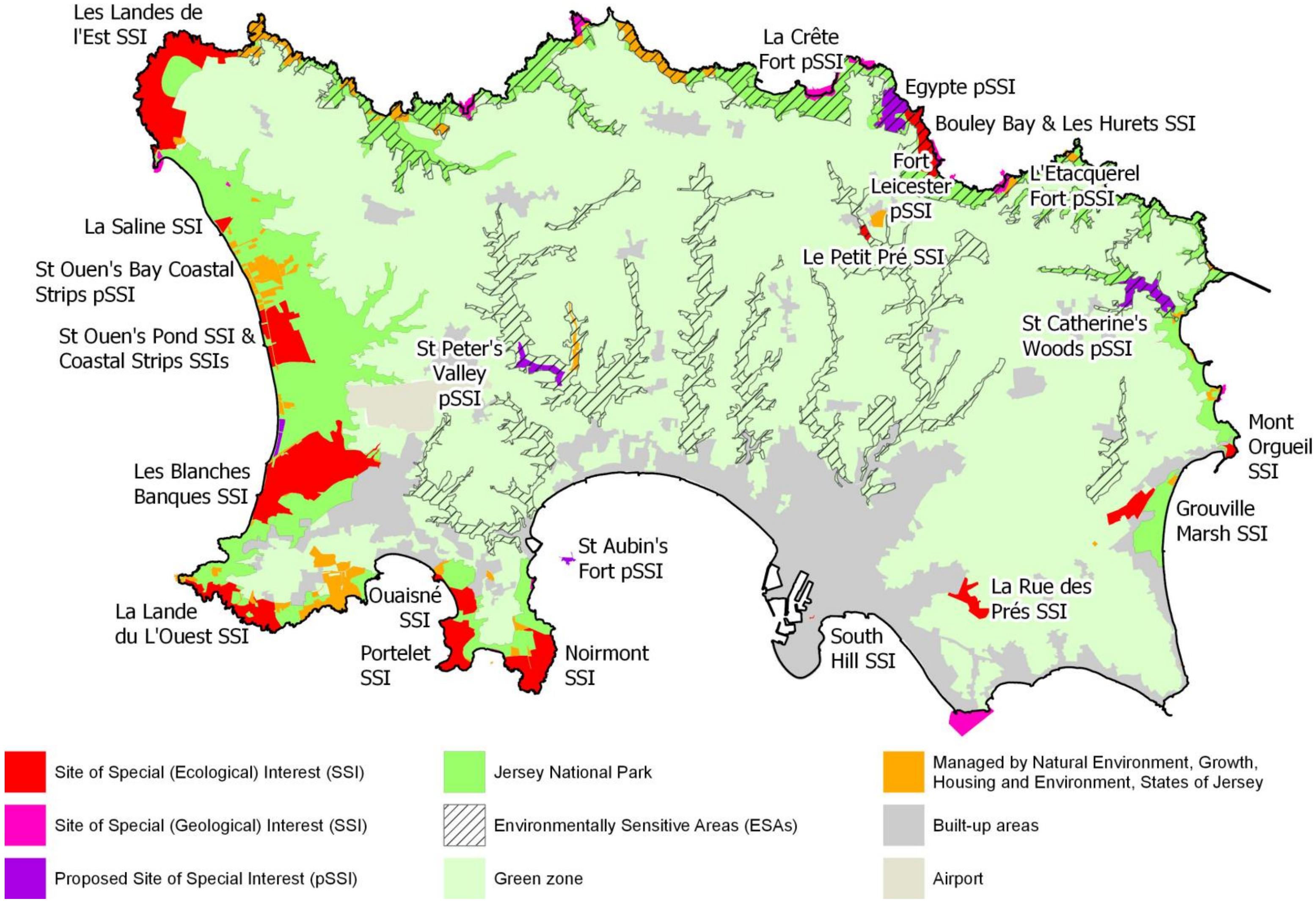

Figure 1 Map of Jersey showing landscape protection designations.

Table 4 Landscape classifications related to protections from development and other activities which may negatively affect character. Rankings are based on the level of protection each classification affords a site and the wildlife within it. The total area covered, and percentage of total land area within that designation are shown.

Rank	Classification	No. sites	Area (ha)	Land area (%)	Description
1	Sites of Special Interest (SSI)	43	524.6	4.4	SSIs are legally designated (Planning and Building (Jersey) Law 2002) based on their special ecological and/or geological interest, and consequently receive additional regulatory power to control works (including but not limited to development) which might affect the special interest of the site.
	ecological	*21*	*463.3*	*3.9*	
	geological	*22*	*75.7*	*0.6*	
2	Jersey National Park (JNP) *(terrestrial portion of the island of Jersey only)*	1	1923.0	16.0	The National Park is designated by policy in the Island Plan, affording it the highest level of policy protection from development with the aims of protecting both the landscape character and the conservation and enhancement of its natural beauty, wildlife and cultural heritage.
3	proposed Sites of Special Interest (pSSI)				These are sites proposed for legal SSI designation but that hold no formal status. However, with the intention for them to be designated as SSIs published, the ecological value of a site may be better known and used to inform the planning process and conservation management more effectively.
	ecological	*9*	*58.4*	0.5	
4	Environmentally Sensitive Areas (ESAs)	17	2796.0	23.2	These sites hold no formal status, but the intention for them to be designated is published and so the ecological value of a site may be better known and used to inform the planning process and conservation management more effectively.
5	Local Wildlife Sites	*	*		These are not currently defined in Jersey and hold no formal status, but are recognised in the UK as areas of importance to wildlife. Knowledge of their ecological value may inform the planning process and their conservation management.
6	Green Zone	1	8407.6	69.9	The Green Zone is defined by policy in the Island Plan and aims to protect landscape character by protecting areas from development. It is not directly linked to the protection of biodiversity, but may achieve benefits for conservation through its implementation.

* Values are not given to Local Wildlife Sites as they are not defined and make up many parcels of land.

Study Species

Step 1 – Identifying and reviewing study species

1.1 Criteria for selecting species

A preliminary selection of focal species was identified through discussion with stakeholders including local species experts, applying the following criteria:

1. Species is not completely widespread throughout the island
2. Species records are
   a. not heavily biased by survey effort, ***or***
   b. any survey biases can be accounted for
3. Sufficient records of high accuracy[2] from between 2007 and 2017 are available to construct a species distribution model
4. Species are
   a. of conservation concern; protected or proposed[3] for protection under either the Conservation of Wildlife Law (Jersey) 2000 or the Conservation of Wildlife (Protected Plants) (Jersey) Order 2009, ***or***
   b. representative of the distribution of species or habitat types or conservation concern otherwise unaccounted for.

The resulting species list included plants, fungi, insects, mammals, reptiles and amphibians. Birds were excluded due to a lack of data on nesting sites and their ability to traverse across the island with ease. However, we account for their needs later in this report.

1.2 Focal species

A total of 17 focal species or species groups (genera) were selected for species distribution modelling. These are summarised in Table 5, and details on their ecology and conservation status are reviewed in Appendix B, in addition to broader assessments of dispersal and movement capabilities of Jersey's protected species. Plants were dominated by orchid species (class Liliopsida) which appear to be better recorded than other flora; perhaps due to their charismatic and overt appearance and specific habitats making them easier to locate

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[2] We consider high accuracy records to be those that have been validated constituting an accurate species identification, and high geographic accuracy within 10 metres of the coordinates provided.

[3] A consultation on a new draft wildlife law was being undertaken during the writing of this report. Therefore, references to wildlife conservation laws and protected species schedules reflect those available at the time of writing (true as of July 2018), and may differ from those in place at the time of reading.

and be of greater popularity (Troudet et al. 2017). Although several invertebrate species were recommended for this study, only the field cricket (*Gryllus campestris*) had sufficient records (Table 8). Those species that could not be included at this stage are evaluated later on through other approaches. Long-eared bat roosts (*Plecotus* spp.) and waxcap fungi (*Hygrocybe* spp.) were modelled at the genus level as intra-genus members were considered to have similar habitat associations (Jersey Bat Group and Société Jersiaise Mycology Section personal communications).

The protected species reviewed were highly variable in their movement and dispersal abilities (Appendix B). Given these findings and the overall aim of producing a well-connected network for a wide variety of species, we use a precautionary approach that would allow movement of dispersal-limited species, but that also contained patches with sufficient size to support the most wide-ranging species. Though we refer to individual distances and ranges in our review, the area encompassed by a functioning population is considerably larger than that of an individual. Therefore, to provide areas that are suitable for not only individuals, but also entire populations to move through and inhabit, we must ensure those areas are of a sufficient magnitude.

Table 5 Summary table of focal species included in this study, showing their common and scientific names, protected status within Jersey and the UK and the number of high accuracy records available (No. obs.). Protections are categorised as follows for species listed under: [a] the Conservation of Wildlife (Jersey) Law 2000 (CWL2000) or the Conservation of Wildlife (Protected Plants) (Jersey) Order 2009 (CWL2009); [b] a Biodiversity Action Plan (BAP) in Jersey (Jer) or the UK; [c] the Wildlife and Countryside Act 1981 (Great Britain only); [d] The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention); [e] The Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention); [f] the EC Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (also known as the Habitats Directive); [g] the Agreement on the Conservation of Populations of European Bats (EUROBATS); and [h] The Conservation of Habitats and Species Regulations 2017 (shown here as TCHSR) (Great Britain only).

[i] Number of observations (records) are those with ≤ 10 metres accuracy and recorded between 2007 and 2017, and have been validated but prior to spatial filtering of records to reduce spatial autocorrelation. Observation numbers for bats are of roost locations only.

For species groups (identified by 'spp.'), the full list of species from which occurrence data were pooled can be found in Table 8.

Species	CWL2000 / CWL2009[a]	BAP[b]	WACA 1981[c]	Bern[d]	CMS[e]	Habitats Directive[f]	EUROBATS[g]	TCHSR[h]	No. obs.[i]
Amphibians									
Western toad (*Bufo spinosus*)	CWL2000	Jer	–	–	–	–	–	–	267
Reptiles									
Grass snake (*Natrix helvetica*)	CWL2000	Jer / UK	Sch. 5	App. 3	–	–	–	–	1197
Mammals									
Jersey bank vole (*Myodes glareolus* ssp. *caesarius*)	CWL2000	Jer	–	–	–	–	–	–	121
Common pipistrelle bat (*Pipistrellus pipistrellus*)	CWL2000	Jer*	Sch. 5	App. 2, 3	App. 2	Ann. 4	Ann. 1	Sch. 2	108
Long-eared bats (*Plecotus* spp.)	CWL2000	Jer* / UK†	Sch. 5	App. 2	App. 2	Ann. 4	Ann. 1	Sch. 2	40
Red squirrel (*Sciurus vulgaris*)	CWL2000	Jer / UK	Sch. 5	App. 3	–	–	–	–	97
Insects									
Field cricket (*Gryllus campestris*)	Proposed	Jer / UK	Sch. 5	–	–	–	–	–	39

Table 5 continued

Species	CWL2000 / CWL2009[a]	BAP[b]	WACA 1981[c]	Bern[d]	CMS[e]	Habitats Directive[f]	EUROBATS[g]	TCHSR[h]	No. obs.[i]
Fungi									
Waxcap fungi (*Hygrocybe* spp.)	–	–	–	–	–	–	–	–	174
Scaly stalkball (*Tulostoma melanocyclum*)	Proposed	UK	–	–	–	–	–	–	17
Plants									
Green-winged orchid (*Anacamptis morio*)	CWL2009	–	–	–	–	–	–	–	56
Pyramidal orchid (*Anacamptis pyramidalis*)	CWL2009	–	–	–	–	–	–	–	46
Southern marsh-orchid (*Dactylorhiza praetermissa*)	CWL2009	–	–	–	–	–	–	–	20
Lizard orchid (*Himantoglossum hircinum*)	CWL2009	Jer	Sch. 8	–	–	–	–	–	20
Early-purple orchid (*Orchis mascula*)	CWL2009	–	–	–	–	–	–	–	22
Jersey buttercup (*Ranunculus paludosus*)	CWL2009	–	–	–	–	–	–	–	14
Ragged robin (*Silene flos-cuculi*)	–	–	–	–	–	–	–	–	35
Autumn lady's-tresses (*Spiranthes spiralis*)	CWL2009	–	–	–	–	–	–	–	86

* Bats listed under one BAP in Jersey

† UK BAP exists for the brown long-eared bat (*P. auritus*)

Data analysis

Step 2 – Species Distribution Modelling

Occurrence records

Occurrence records from the 17 focal species were restricted to 2007–2017 to reduce the risk of recently mapped predictor variables (e.g. landcover) being inaccurate in relation to old occurrences. We also excluded any records documented as having a geographical accuracy poorer than 10 metres. Any records that had uncertain provenance, that had possibly been misidentified to species level or were obviously inaccurate (e.g. in the sea) were also excluded. The remaining records were filtered to produce a set of occurrences that were spaced by at least 100 metres. This spatial filtering step was repeated 20 times and the set that retained the most occurrences was selected for further analysis. This reduces the effects of spatial bias (e.g. by a surveyor sampling the same area repeatedly). Further issues surrounding biases in biodiversity records are discussed later in the document.

Predictor layers

Scientific literature and species experts were consulted to identify potential drivers of landscape suitability for each focal species and appropriately parameterise each species distribution model (see Appendix B). Where possible, each driver was mapped across the island in ArcGIS Pro to produce a layer matching in extent and projection of a Jersey base map.

Environmental variables

Environmental variables were downloaded from WorldClim (www.worldclim.org), consisting of data from WorldClim Version 2.0 (Fick and Hijmans 2017) at a resolution of 30 seconds (equivalent to ~1 km^2) averaged between 1970–2000. Each of the 19 bioclimatic variables (see Appendix C) were clipped to the extent of Jersey, the grids were converted to points and mathematical estimation based on the values of nearby points (kriging) was used to create a smooth surface at 25 metre resolution in ArcGIS Pro. Following inspection, we decided to exclude environmental variables from further analyses as they had limited variation over the island given its relatively small extent.

Landcover

Landcover type is often the most important variable in species distribution models as it is a fundamental driver of species occurrence. We derived a landcover layer from the Phase 1 Habitats layer provided by Natural Environment, Growth, Housing and Environment, States of

Jersey. This file contained detailed descriptions of landcover types but exhibited holes which would affect subsequent analysis. These were filled with the relevant data from GIS maps of buildings, roads and other land parcels to provide a complete map. This was then reclassified to contain the relevant landcover description from 23 categories (Table 6; Figure 2) and validated using close visual inspection of maps to check for gaps and inconsistencies, with high resolution aerial imaging as a basis for visual checks. These data were resampled to a resolution of 25 metres, assigning a landcover value to each cell based on the maximum combined area of the landcover types present. This resampling can cause smaller features to be absorbed by more dominant landcover features and subsequently 'lost' during analysis. Therefore, we generated layers representing the Euclidean (straight-line) distance to small or linear features (roads, boundaries, freshwater, amphibians as a representation of grass snake prey) and to each landcover class. We also calculated density layers within a 250 m radius for permanent anthropogenic structures (buildings, roads and street lighting) and human population (Table 7).

Collinearity

Correlations between variables in each species' variable set were tested in ENMTools v1.4.4 (Warren et al. 2010). Where two variables had Pearson's correlations $R^2 \geq 0.7$, the variable considered to have the most ecological relevance was retained and the other removed. The Variance Inflation Factor (VIF) for each remaining variable in each species variable set was then calculated in R (R Core Team 2018) tools using the *vifcor* and *vifstep* functions in the package *usdm* (Naimi 2015). All VIF values were < 3 (Zuur et al. 2010), and so no further variables were removed. The final set of predictor variables tested are shown in Table 7.

Model settings

We used the ClogLog transform output in MaxEnt, which can be interpreted as predicted probability of presence with estimates between 0 (low) and 1 (high). However here, we consider it as the predicted probability of suitability due to the inherent detectability issues of many species (e.g. Ward et al. 2017). All models were run in MaxEnt V.3.4.1 (available from https://biodiversityinformatics.amnh.org/open_source/maxent/) (Phillips et al. 2018). Due to small sample size for some species, k-fold cross-validation was used to generate test and training datasets; whereby the data is partitioned and tested and trained using each partition. Each model was run up to 20 times (less for species with small numbers of occurrence records), with a maximum of 5,000 iterations and no more than 10,000 background points. All other settings were left as the defaults.

Model selection

Models were assessed using threshold-independent measures and inspection of jackknife responses (a form of resampling to test the importance of each variable in the model, by excluding variables one at a time, and also running models with a single variable one at a time). Threshold-independent measures consisted of the area under the curve of the test data (AUC_{test}) (Phillips et al. 2006), and the difference (AUC_{diff}) between training AUC (AUC_{train}) and testing AUC (AUC_{test}) values (Warren and Seifert 2011), calculated as

$AUC_{diff} = AUC_{train} - AUC_{test}$.

Of these, the optimum model was that which had the highest AUC_{test} and lowest AUC_{diff} values whilst producing biologically plausible outputs. We then tested varying regularisation values for each species' optimum model to identify the value where the risks of over-fitting and unnecessary model complexity were minimised (Merow et al. 2013), using the same threshold-independent and jackknife measures to assess their performance. Visual inspection of the maps produced was also used to ensure biological plausibility. The model showing the best overall performance and with the most suitable regularisation value was then selected as the final model for that species, from which the influence of predictor variables was assessed from permutation importance and by inspecting the outputs from jackknife tests.

Table 6 Landcover classifications derived from data provided by Natural Environment, Growth, Housing and Environment, States of Jersey. The feature types incorporated are shown, and the proportion (%) of the island that they encompass in vector format and after they have been converted to 25 m raster cell size (shown as vector/raster).

ID	Landcover	Feature types	%
1	Arable	Arable; Arable, short term ley	39.0 / 40.8
2	Bare ground (natural)	Hard cliff; Shingle; Rock; Soft cliff; Open dune	1.2 / 1.0
3	Bare ground (unnatural)	Roads; Pathways; Pavement; Driveway; Car parks; Quarry; Pier; Sea wall; Statue/monument; Steps; Dam wall	9.2 / 7.4
4	Bracken	Continuous bracken, open; Continuous bracken, scrub underlay	3.6 / 3.7
5	Broadleaved woodland	Woodland, planted broadleaved; Woodland, semi-natural, broadleaved	5.7 / 5.9
6	Brownfield	Brown-field site	0.1 / 0.1
7	Building	Glasshouse; Polytunnel; Lighthouse; Minor building; Major building; Ruin; Multi property; Tank	5.4 / 4.1
8	Coastal grassland	Coastal grassland; Coastal grassland, Molinia; Coastal grassland, species rich short turf	0.7 / 0.7
9	Coastal heath	Coastal heathland	0.7 / 0.7
10	Coniferous woodland	Woodland, planted coniferous	0.2 / 0.2
11	Dune grassland	Dune grassland	1.3 / 1.3
12	Dune heath	Dune heath	<0.1 / <0.1
13	Dune marram dominated	Dune marram dominated	0.4 / 0.4
14	Garden	Gardened; Swimming pool	5.9 / 6.4
15	Hottentot fig	Hottentot fig	0.1 / 0.1
16	Improved grassland	Improved grassland; Verge; Amenity grassland; Parkland; Golf course	18.9 / 19.7
17	Mixed woodland	Woodland, planted mixed; Woodland	2.0 / 2.1
18	Orchard / plantation	Woodland, plantation (orchard etc.)	0.6 / 0.6
19	Scrub	Dense scrub, blackthorn; Dense scrub, bramble; Dense scrub, gorse; Dense scrub, sallow; Dense scrub, other; Dune dwarf scrub	2.8 / 2.7
20	Semi-improved grassland	Semi-improved grassland	0.2 / 0.2
21	Tall ruderal	Tall ruderal	0.5 / 0.5
22	Unimproved grassland	Unimproved grassland	0.1 / <0.1
23	Wetland	Dune slack; Freshwater; Reservoir; Pond; Running water; Marshy-grassland, Oenanthe dominated; Marshy grassland, semi-improved; Marshy-grassland, unimproved; Swamp; Water	1.4 / 1.3

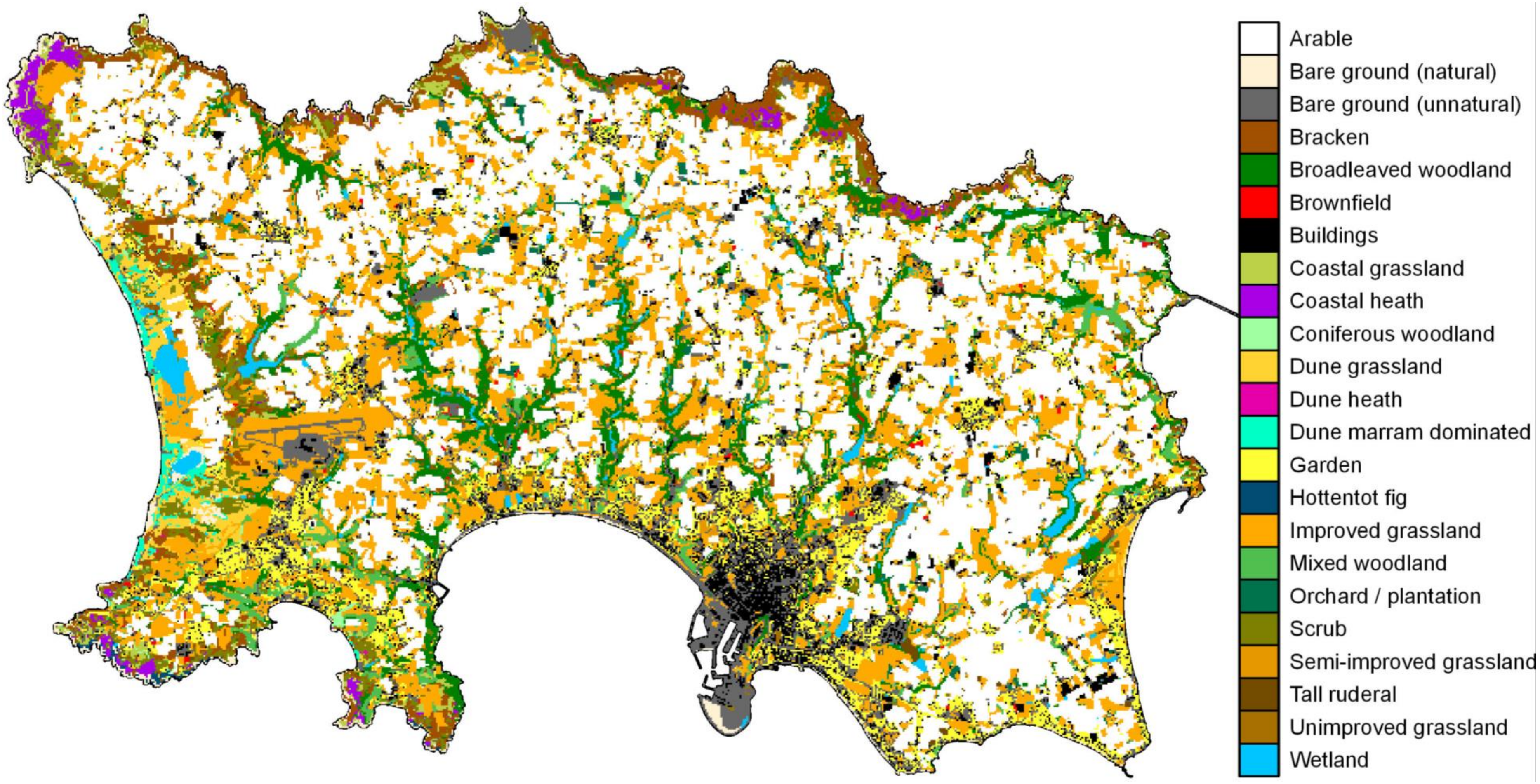


Figure 2 Map of Jersey showing the 23 landcover classes at a 25 metre raster resolution. Each landcover class is colour-coded and shown in the legend provided.

Table 7 Summary table of predictor layers used during model building. Units are indicated in *italics* in square brackets [ ].

Variable	Description
aspect	Topographical aspect, derived from a digital elevation model [*degrees*]
building density	Kernel density within a 250 m radius [*buildings per square metre*]
distance to (all) bare ground	Euclidean distance to all bare ground landcover classes (natural and unnatural) [*metres*]
distance to (all) boundary features	Euclidean distance to all boundaries [*metres*]
distance to (all) grassland	Euclidean distance to all grassland landcover classes (coastal, dune, dune marram dominated, improved, semi-improved, unimproved, orchard / plantation, tall ruderal) [*metres*]
distance to (all) scrub	Euclidean distance to all scrub landcover classes (bracken, coastal heath, dune heath, scrub) [*metres*]
distance to (all) woodland	Euclidean distance to all woodland landcover classes (coniferous, broadleaved, mixed) [*metres*]
distance to banks	Euclidean distance to bank boundary features [*metres*]
distance to (natural) bare ground	Euclidean distance to the natural bare ground landcover class [*metres*]
distance to bracken	Euclidean distance to the bracken landcover class [*metres*]
distance to cemeteries	Euclidean distance to cemeteries [*metres*]
distance to coastal grassland	Euclidean distance to the coastal grassland landcover class [*metres*]
distance to coastal heathland	Euclidean distance to the coastal heathland landcover class [*metres*]
distance to coniferous woodland	Euclidean distance to the coniferous woodland landcover class [*metres*]
distance to dry stone walls	Euclidean distance to dry stone wall boundary features [*metres*]
distance to dune grassland	Euclidean distance to the dune grassland landcover class [*metres*]
distance to dune heathland	Euclidean distance to the dune heathland landcover class [*metres*]
distance to dune marram	Euclidean distance to the dune marram grassland landcover class [*metres*]
distance to gardens	Euclidean distance to the garden landcover class [*metres*]
distance to historic buildings	Euclidean distance to historic buildings (mapped in 1935) [*metres*]
distance to improved grassland	Euclidean distance to the improved grassland landcover class [*metres*]
distance to major buildings	Euclidean distance to major buildings [*metres*]
distance to mixed woodland	Euclidean distance to the mixed woodland landcover class [*metres*]
distance to ponds and reservoirs	Euclidean distance to ponds and reservoirs [*metres*]
distance to roads	Euclidean distance to roads [*metres*]
distance to ruderal	Euclidean distance to the ruderal landcover class [*metres*]
distance to ruins	Euclidean distance to ruins [*metres*]
distance to scrub	Euclidean distance to the scrub landcover class [*metres*]

Table 7 continued

Variable	Description
distance to semi-improved grassland	Euclidean distance to the semi-improved grassland landcover class [*metres*]
distance to squirrel feeders	Euclidean distance to squirrel feeders [*metres*]
distance to streams	Euclidean distance to streams [*metres*]
distance to toads	Euclidean distance to (accurate) toad locations [*metres*]
distance to unimproved grassland	Euclidean distance to the unimproved grassland landcover class [*metres*]
distance to built-up areas	Euclidean distance to built-up areas (as shown in 2011 Island Plan) [*metres*]
distance to verges	Euclidean distance to road verges [*metres*]
distance to wetlands	Euclidean distance to the wetland landcover class [*metres*]
landcover type	23 discrete landcover classes (see Table 6; Figure 2)

Step 3 – Habitat Concentration Areas (HCAs)

Habitat Concentration Areas (*sensu* WHCWG 2010) are those areas expected to have the highest suitability for a given species or selection of species. We identified these by applying a binary threshold on the average MaxEnt output for each species. We chose the maxSSS threshold which maximises the sum of sensitivity and specificity (Liu et al. 2005; Peterson et al. 2011). These areas were further reduced by removing small, disaggregated patches. The areas to remove were selected by calculating (i) the Proximity Index (Gustafson and Parker 1994) at a radius of 20 km (to include all patches in the landscape) and (ii) Patch Area values in FRAGSTATS v4.2 (McGarigal et al. 2012). The Proximity Index is a measure of patch isolation, but is sensitive to patch size and assigns lower values to larger patches (Hargis et al. 1998). Therefore, a Modified Proximity Index (MPI) was calculated by multiplying the two metrics following Bani et al. (2006) to produce a metric that accounted for patch size. We then removed patches that had an MPI value < 0.6. We considered these small, isolated patches to hold less management value than larger, aggregated areas. That is not to say that they aren't useful, but that perhaps they do not provide such a strong contribution to the function of the metapopulation.

To further refine HCAs, we removed portions of the map containing unsuitable features. Where appropriate, these were water bodies, unnatural bare ground (e.g. roads, pavements), buildings, tennis courts, recreation fields of no discernible quality to wildlife and swimming pools. The final HCAs were assessed for overlap between species to look for similarities, and contrasted against the designations listed in Table 4 (excluding Local Wildlife Sites) to assess their performance in protecting Jersey's biodiversity. The HCAs from each species were also overlaid to create a 'hotspot' map at a resolution of 25 metres. This was done with all 17 focal species, with a subset excluding any species with strong (≥ 10%) HCA predictions in built-up areas (referred to as 'urban-dwellers'), and a third subset of only urban-dwellers.

3.1 Overlay of raw occurrences

In Step 2 we have focused on species with sufficient quality and quantity of data to undertake species distribution modelling. This is a time consuming process, and has restrictions in place due to data availability and suitability for many species. Though we have utilised a number of species across different taxonomic groups, there is still a possibility that key habitats and HCAs for Jersey's wildlife could be missed. Therefore, as a validation step, we have chosen to utilise raw species records and expert opinion in lending further support to identifying HCAs.

We used 10,113 raw occurrence records (2007–2017, all geographic accuracies) from 98 species listed as protected or proposed under the CWL (Table 8). We note that, though the

CWL 2000 lists all wild birds except crows, magpies and pigeons under Article 2(2), we only included records for species listed under Article 2(3) due to the potentially large number of birds (Young et al. 2016) that could otherwise be included. Many of these are variable in their presence (i.e. resident or migrant, seasonal visitor). Moreover, a number of them are sea, coast or shore-dwellers; areas which are not considered in this study. A further assessment of coverage for important bird areas is discussed below.

Of the species listed or proposed for protection under the CWL, no records were available for the Kentish plover (*Charadrius alexandrinus*), horseshoe bat roosts (*Rhinolophidae* spp.), maidenhair fern (*Adiantum capillus-veneris*), round-leaved sundew (*Drosera rotundifolia*), Jersey cudweed (*Gnaphalium luteo-album*), motherwort (*Leonurus cardiaca*), fine-leaved sandwort (*Minuartia hybrida*), hoary plantain (*Plantago media*), long-headed clover (*Trifolium incarnatum ssp. molinerii*), blue water-speedwell (*Veronica anagallis-aquatica*) and yellow-vetch (*Vicia lutea*). Those tested included 31 animal species listed under the CWL 2000, 58 plants listed under the CWL 2009 and nine invertebrate species proposed for protection. A further 26 fungi species including 23 waxcap species (*Hygrocybe* spp.) were also tested due to their inclusion in the distribution modelling phase following species expert consultation.

The Euclidean (straight-line) distance between each species record and the nearest identified HCA was calculated. From this, we calculated the percentage of records that fell within HCAs, and the average distances at which records occurred from HCAs. Smaller distances indicated records occurred near HCAs, and a distance value of 0 indicated records occurred within HCAs. The variable geographic accuracy of data used in this step meant that records falling outside of HCAs may have actually occurred within them but that coordinate data was inaccurate. The inverse may also be true. Such inaccuracies are an issue in biological recording, in that records may either be recorded to a wider area (e.g. 1km square for National Amphibian and Reptile Recording Scheme (NARRS) data), or data may be deposited with insufficient information such as a low resolution grid reference, just a postcode, street name or even the parish of origin. This has a number of consequences covered more fully in the Discussion.

3.2 Hotspot map of raw occurrences

In addition, a visual representation of raw CWL species distribution was created. Specifically, we generated a heatmap overlaying the records, with each species contributing an individual raster. The overlay then shows the number of species occurring within that grid. This was generated at 100 m resolution to provide broader coverage and account for geographical inaccuracies in the coordinates of the occurrence points.

3.3 Expert-identified areas

It is known that some taxonomic groups or individual species remain poorly recorded. This can be due to a number of reasons, discussed in more detail in the Discussion. In order to overcome this and ensure no HCAs were missed out, a final approach was taken whereby ornithological experts were engaged in order to identify areas they deemed most important for birds, as this group was not included within our focal species and subsequent steps. These areas were then cross-referenced with our existing HCAs to see if they were congruent.

Table 8 Species records overlaid with Habitat Concentration Areas (HCAs). Records were limited to between 2007–2017 but included all levels of geographic accuracy. Records consist of only those found within Jersey, and not in coastal zones or outlying islands. Distances are shown with standard deviations.

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Amphibians			**658**	71.58	3.38 (9.39)
*Bufo spinosus**	Common toad	CWL2000	551	70.24	3.50 (9.68)
Lissotriton helveticus	Palmate newt	CWL2000	56	62.50	4.91 (10.07)
Rana dalmatina	Agile frog	CWL2000	51	96.08	0.39 (1.96)
Birds			**990**	93.74	1.88 (12.68)
Accipiter nisus	Sparrowhawk	CWL2000	130	93.85	0.69 (3.56)
Alcedo atthis	Kingfisher	CWL2000	77	92.21	1.20 (5.98)
Cettia cetti	Cetti's warbler	CWL2000	139	94.96	0.58 (2.89)
Charadrius alexandrinus	Kentish plover	CWL2000	0	–	–
Emberiza cirlus	Cirl bunting	CWL2000	32	84.38	3.14 (8.05)
Falco peregrinus	Peregrine	CWL2000	181	87.85	6.28 (27.09)
Panurus biarmicus	Bearded tit	CWL2000	73	97.26	0.82 (4.93)
Serinus serinus	Serin	CWL2000	3	66.67	5.00 (8.66)
Sylvia undata	Dartford warbler	CWL2000	345	98.26	0.36 (4.26)
Tyto alba	Barn owl	CWL2000	10	50.00	16.51 (21.73)
Invertebrates			**242**	85.95	1.86 (8.14)
Chorthippus vagans	Heath grasshopper	Proposed	17	94.12	0.88 (3.64)
Chrysotoxum vernale	Hoverfly	Proposed	8	100.00	0.00 (0.00)
Colletes cunicularius	Vernal colletes bee	Proposed	12	91.67	0.42 (1.44)
Euchorthippus elegantulus	Jersey grasshopper	Proposed	13	100.00	0.00 (0.00)
Formica pratensis	European red wood ant	Proposed	39	92.31	0.64 (2.35)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
*Gryllus campestris**	Field cricket	Proposed	56	94.64	1.43 (8.78)
Lestes barbarus	Southern emerald damselfly	Proposed	18	88.89	0.56 (1.62)
Papilio machaon	Swallowtail	Proposed	70	70.00	3.06 (6.61)
Satyrium w-album	White-letter hairstreak	Proposed	9	66.67	11.17 (29.85)
Mammals			**5122**	56.48	10.48 (20.73)
Crocidura suaveolens	Lesser white-toothed shrew	CWL2000	25	88.00	0.60 (1.66)
Erinaceus europaeus	Hedgehog	CWL2000	4189	50.32	12.08 (20.88)
Myodes glareolus ssp. *caesarius**	Jersey bank vole	CWL2000	154	90.26	2.73 (8.82)
Rhinolophidae[†]	Bats, horseshoe (all species)	CWL2000	0	–	–
*Sciurus vulgaris**	Red squirrel	CWL2000	574	83.28	3.45 (21.31)
Sorex coronatus	Common or French shrew	CWL2000	3	100.00	0.00 (0.00)
Vespertilionidae[†]	Bats, typical (all species)	CWL2000	***177***	80.79	3.72 (15.69)
Eptesicus serotinus	Serotine bat	CWL2000	4	100.00	0.00 (0.00)
Myotis emarginatus	Geoffroy's bat	CWL2000	1	100.00	0.00 (0.00)
Myotis mystacinus	Whiskered bat	CWL2000	1	100.00	0.00 (0.00)
Myotis nattereri	Natterer's bat	CWL2000	2	100.00	0.00 (0.00)
Pipistrellus kuhlii	Kuhl's pipistrelle	CWL2000	3	66.67	1.67 (2.89)
Pipistrellus nathusii	Nathusius' pipistrelle	CWL2000	11	72.73	2.27 (4.10)
*Pipistrellus pipistrellus**	Common pipistrelle bat	CWL2000	108	78.70	2.51 (10.49)
Pipistrellus pygmaeus	Soprano pipistrelle bat	CWL2000	7	100.00	0.00 (0.00)
*Plecotus auritus**	Brown long-eared bat	CWL2000	5	100.00	0.00 (0.00)
*Plecotus austriacus**	Grey long-eared bat	CWL2000	35	80.00	10.20 (29.43)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Fungi			**280**	**97.14**	**0.18 (1.11)**
Battarrea phalloides	Sandy stiltball	–	13	84.62	0.77 (1.88)
Myriostoma coliforme	Pepperpot	–	10	100.00	0.00 (0.00)
*Tulostoma melanocyclum**	Scaly stalkball	–	18	100.00	0.00 (0.00)
Hygrocybe spp.*	Waxcaps	–	**239**	97.49	0.17 (1.11)
*Hygrocybe autoconica**		–	6	100.00	0.00 (0.00)
*Hygrocybe calyptriformis**	Pink waxcap	–	16	100.00	0.00 (0.00)
*Hygrocybe ceracea**	Butter waxcap	–	5	100.00	0.00 (0.00)
*Hygrocybe chlorophana**	Golden waxcap	–	11	90.91	0.45 (1.51)
*Hygrocybe coccinea**	Scarlet waxcap	–	19	100.00	0.00 (0.00)
*Hygrocybe conica**	Blackening waxcap	–	37	94.59	0.27 (1.15)
*Hygrocybe conicoides**	Dune waxcap	–	1	100.00	0.00 (0.00)
Hygrocybe constrictospora		–	0	–	–
*Hygrocybe flavipes**		–	8	100.00	0.00 (0.00)
Hygrocybe fornicate		–	0	–	–
*Hygrocybe glutinipes**		–	1	100.00	0.00 (0.00)
*Hygrocybe insipida**		–	5	100.00	0.00 (0.00)
Hygrocybe intermedia	Fibrous waxcap	–	0	–	–
*Hygrocybe irrigata**	Slimy waxcap	–	6	100.00	0.00 (0.00)
*Hygrocybe marchii**		–	2	100.00	0.00 (0.00)
Hygrocybe miniata	Vermilion waxcap	–	0	–	–
*Hygrocybe mucronella**	Bitter waxcap	–	4	100.00	0.00 (0.00)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Hygrocybe nigrescens		–	0	–	–
Hygrocybe nitrata		–	0	–	–
*Hygrocybe persistens**		–	2	100.00	0.00 (0.00)
*Hygrocybe pratensis**	Meadow waxcap	–	16	93.75	0.31 (1.25)
*Hygrocybe psittacina**	Parrot waxcap	–	27	100.00	0.00 (0.00)
*Hygrocybe psittacina var. perplexa**		–	1	100.00	0.00 (0.00)
*Hygrocybe punicea**	Crimson waxcap	–	4	100.00	0.00 (0.00)
*Hygrocybe quieta**	Oily waxcap	–	5	100.00	0.00 (0.00)
*Hygrocybe reidii**	Honey waxcap	–	11	100.00	0.00 (0.00)
*Hygrocybe russocoriacea**	Cedarwood waxcap	–	1	100.00	0.00 (0.00)
*Hygrocybe splendidissma**		–	1	100.00	0.00 (0.00)
Hygrocybe substrangulata		–	0	–	–
Hygrocybe turunda		–	0	–	–
*Hygrocybe virginea**	Snowy waxcap	–	50	96.00	0.40 (1.98)
Hygrocybe vitelline		–	0	–	–
Plants			**555**	**89.55**	**1.09 (4.15)**
Adiantum capillus-veneris	Maidenhair fern	CWL2009	0	–	–
Agrimonia eupatoria	Agrimony	CWL2009	6	66.67	1.67 (2.58)
Agrimonia procera	Fragrant agrimony	CWL2009	1	100.00	0.00 (0.00)
Allium sphaerocephalon	Round-headed leek	CWL2009	1	100.00	0.00 (0.00)
Anacamptis laxiflora	Loose-flowered orchid	CWL2009	28	85.71	2.32 (6.87)
*Anacamptis morio**	Green-winged orchid	CWL2009	58	98.28	0.09 (0.66)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
*Anacamptis pyramidalis**	Pyramidal orchid	CWL2009	49	93.88	0.92 (4.17)
Anogramma leptophylla	Jersey fern	CWL2009	23	60.87	2.39 (3.33)
Apium graveolens	Wild celery	CWL2009	7	100.00	0.00 (0.00)
Asparagus officinalis var. prostratus	Wild asparagus	CWL2009	1	100.00	0.00 (0.00)
Baldellia ranunculoides	Lesser water-plantain	CWL2009	1	100.00	0.00 (0.00)
Carex binervis	Green-ribbed sedge	CWL2009	13	76.92	1.99 (4.55)
Carex divulsa ssp. *divulsa*	Grey sedge	CWL2009	6	66.67	4.17 (6.65)
Carex echinata	Star sedge	CWL2009	3	100.00	0.00 (0.00)
Carex pseudocyperus	Cyperus sedge	CWL2009	1	100.00	0.00 (0.00)
Carum verticillatum	Whorled caraway	CWL2009	4	100.00	0.00 (0.00)
Centunculus (Anagallis) minima	Chaffweed	CWL2009	1	100.00	0.00 (0.00)
Cicendia filiformis	Yellow centaury	CWL2009	3	100.00	0.00 (0.00)
Cyperus fuscus	Brown galingale	CWL2009	2	100.00	0.00 (0.00)
Dactylorhiza fuchsia	Common spotted-orchid	CWL2009	9	100.00	0.00 (0.00)
Dactylorhiza incarnata	Early marsh-orchid	CWL2009	1	100.00	0.00 (0.00)
Dactylorhiza maculata	Heath spotted-orchid	CWL2009	11	100.00	0.00 (0.00)
*Dactylorhiza praetermissa**	Southern marsh-orchid	CWL2009	30	86.67	2.00 (6.38)
Dianthus gallicus	Jersey pink	CWL2009	1	100.00	0.00 (0.00)
Drosera rotundifolia	Round-leaved sundew	CWL2009	0	–	–
Elatine hexandra	Six-stamened waterwort	CWL2009	3	100.00	0.00 (0.00)
Eriophorum angustifolium	Common cottongrass	CWL2009	3	100.00	0.00 (0.00)
Euphorbia paralias	Sea spurge	CWL2009	8	100.00	0.00 (0.00)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Falcaria vulgaris	Longleaf	CWL2009	7	42.86	10.01 (10.20)
Gnaphalium luteo-album	Jersey cudweed	CWL2009	0	–	–
*Himantoglossum hircinum**	Lizard orchid	CWL2009	25	100.00	0.00 (0.00)
Hypericum linariifolium	Toadflax-leaved St John's-wort	CWL2009	4	100.00	0.00 (0.00)
Hypochaeris maculata	Spotted cat's-ear	CWL2009	3	66.67	1.67 (2.89)
Kickxia elatine	Sharp-leaved fluellen	CWL2009	6	83.33	0.83 (2.04)
Leonurus cardiaca	Motherwort	CWL2009	0	–	–
Limonium normannicum	Alderney sea-lavender	CWL2009	12	75.00	3.75 (7.11)
Limonium vulgare	Common sea-lavender	CWL2009	7	100.00	0.00 (0.00)
Luzula multiflora	Heath wood-rush	CWL2009	24	91.67	0.42 (1.41)
Luzula sylvatica	Great wood-rush	CWL2009	3	100.00	0.00 (0.00)
Lysimachia nemorum	Yellow pimpernel	CWL2009	2	100.00	0.00 (0.00)
Lythrum hyssopifolium	Grass-poly	CWL2009	7	71.43	2.86 (5.67)
Matthiola sinuata	Sea stock	CWL2009	3	100.00	0.00 (0.00)
Minuartia hybrida	Fine-leaved sandwort	CWL2009	0	–	–
Myosotis sicula	Jersey forget-me-not	CWL2009	4	100.00	0.00 (0.00)
Nardus stricta	Mat-grass	CWL2009	3	33.33	4.02 (3.64)
Ophrys apifera	Bee orchid	CWL2009	5	80.00	1.00 (2.24)
Ophrys sphegodes	Early spider orchid	CWL2009	4	100.00	0.00 (0.00)
*Orchis mascula**	Early-purple orchid	CWL2009	26	88.46	0.66 (1.88)
Ornithopus pinnatus	Orange bird's-foot	CWL2009	1	100.00	0.00 (0.00)
Orobanche rapum-genistae	Greater broomrape	CWL2009	4	100.00	0.00 (0.00)

Table 8 continued

Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Plantago media	Hoary plantain	CWL2009	0	–	–
Primula veris	Cowslip	CWL2009	4	100.00	0.00 (0.00)
*Ranunculus paludosus**	Jersey buttercup	CWL2009	14	100.00	0.00 (0.00)
Ranunculus trichophyllus	Thread-leaved water-crowfoot	CWL2009	3	100.00	0.00 (0.00)
Reseda lutea	Wild mignonette	CWL2009	2	50.00	23.05 (32.60)
Rhinanthus minor	Yellow-rattle	CWL2009	3	100.00	0.00 (0.00)
Rumex rupestris	Shore dock	CWL2009	2	100.00	0.00 (0.00)
Salicornia europaea	Glasswort	CWL2009	3	66.67	3.33 (5.77)
*Spiranthes spiralis**	Autumn lady's-tresses	CWL2009	86	90.70	0.55 (1.80)
Succisa pratensis	Devil's-bit scabious	CWL2009	6	100.00	0.00 (0.00)
Trifolium fragiferum	Strawberry clover	CWL2009	3	100.00	0.00 (0.00)
Trifolium incarnatum ssp. molinerii	Long-headed clover	CWL2009	0	–	–
Veronica anagallis-aquatica	Blue water-speedwell	CWL2009	0	–	–
Veronica scutellata	Marsh speedwell	CWL2009	2	100.00	0.00 (0.00)
Vicia lutea	Yellow-vetch	CWL2009	0	–	–
Viola canina	Heath dog-violet	CWL2009	2	100.00	0.00 (0.00)
Zannichellia palustris	Horned pondweed	CWL2009	1	0.00	20.00 (0.00)
Reptiles			**2546**	95.40	0.88 (8.34)
Anguis fragilis	Slow worm	CWL2000	591	93.91	1.78 (15.24)
Lacerta bilineata	Green lizard	CWL2000	527	94.50	1.09 (7.04)
*Natrix helvetica**	Grass snake	CWL2000	1383	97.69	0.29 (2.61)

					Table 8 continued
Species[a]	Common name	Protection[b]	No. records (2007–2017)	% within HCAs	Mean distance (m) to HCAs (SD)
Podarcis muralis	Wall lizard	CWL2000	45	55.56	4.79 (8.25)

[a] Note that binomial species names and classifications are shown as stored in the Jersey Biodiversity Centre database and may be subject to change following taxonomic investigations.

[b] Species protection: CWL2000 = species protected under the Conservation of Wildlife Law (Jersey) 2000; CWL2009 = species protected under the Conservation of Wildlife (Protected Plants) (Jersey) Order 2009; Proposed = species proposed for protection.

* Species is included in Step 2 (distribution modelling phase).

† Bat data consists only of roost records in this study.

Step 4 – Connectivity analyses

Ensuring an ecological community is functional requires not only patches of suitable habitat (e.g. HCAs) but also for these patches to be well connected internally (intra-patch connectivity) and to one another (inter-patch connectivity). The routes through which species disperse or migrate between patches can be referred to as wildlife corridors. These can be thought of as either continuous features suitable for wildlife such as hedgerows, or as stepping stones consisting of habitat patches that occur between more suitable patches. Connectivity is therefore dependent on numerous factors including the size and shape of patches, their distance from one another, their habitat and structure, and the ecology of the species moving through or occurring within patches and corridors.

Approaches to assessing connectivity are often done on a single-species basis, however multi-species approaches are becoming more popular (e.g. Pereira et al. 2017; Khosravi et al. 2018; Schoville et al. 2018) and are likely to provide more meaningful results for biodiversity as a whole. To assess connectivity, we must know (i) which patches of habitat are important to connect, (ii) how our species of interest interact with the landscape (i.e. how well they can disperse and for what purposes), and subsequently (iii) define a resistance surface depicting the species' ability to move through the landscape.

4.1 Patch selection – where to connect?

Our HCAs for each species/group were used as cores between which we wanted to assess connectivity. Each species/group was run separately. As built-up areas are generally unsuitable for protection, and the diversity of land-owners makes it difficult to inform management, we opted to remove built-up areas from HCAs prior to calculating least-cost paths and corridors. However, separate runs including HCAs within built-up areas were included for urban-dwelling species (defined as species with ≥ 10% of their HCAs within built-up areas).

4.2 Resistance surfaces

Studies assessing the ability of organisms to move through a landscape often rely on developing a resistance surface. This represents the ease through which different features of the landscape facilitate or impede movement of the focal organisms. These resistance surfaces can be constructed based on expert opinion (Sawyer et al. 2011), a quantitative assessment of habitat suitability (Poor et al. 2012), movement data (Naidoo et al. 2018) or genetic evidence (Short Bull et al. 2011). From this surface, approaches are used to identify the ‘least-cost-path’ through which the organism may travel between suitable patches of habitat with the lowest cost (energetic / distance).

Here we parameterise our resistance surfaces using a transformation of habitat suitability estimates. The habitat suitability estimates were the ClogLog outputs from the respective species’ final MaxEnt output. These were transformed in to a resistance surface using a linear negative transformation (Wilkinson and Starnes 2016) calculated as

$$R_{lin} = ((1-[MaxEnt\_output])*100)+1 \quad \text{Equation 1}$$

with values rescaled between 1 and 100. To this, we added further resistance for roads and other transport infrastructure with resistance values dependent on their width (e.g. single, dual or triple lane), with wider roads given greater resistance. These values were based on their expected risk of mortality, either from traffic or exposure to predators. Built-up areas were also assigned higher resistance, using building density as a proxy (see Table 7 for further details on its calculation). Building densities ranged between 0 and 0.0053, and were rescaled between 0 (no built-up resistance) and 20 (high built-up resistance). A final resistance layer was added consisting of boundary features. These can have both positive and negative influences on movement, providing shelter and other resources, or by serving as a physical barrier. The former were assigned negative resistance values (i.e. resistance was reduced). All resistance surface values are summarised in Table 9. For each species, the four resistance surfaces (1: negative transformation of MaxEnt habitat suitability, 2: roads, 3: building density and 4: boundary features) were summed to produce a final resistance surface.

Though the transformed MaxEnt surfaces were for specific species, we treated them as representatives for a given ecosystem or niche, and carried out all further steps based on the aim of generating wildlife corridors that would encourage dispersal of the majority of Jersey’s terrestrial animal species. Given the difficulties in modelling the dispersal of plants and fungi, we did not model these specifically but assumed a well-functioning landscape for animals would also benefit plants and fungi.

Table 9 Resistance costs associated to different layers. CWD is the cost weighted distance, calculated as **resistance** * **25 m** (cell size).

Type	Description	Resistance	CWD
Roads	Cycle path	1	25
Roads	Track	1	25
Roads	Car park	3	75
Roads	Layby	3	75
Roads	Slipway	3	75
Roads	999	10	250
Roads	Pedestrianised (i.e. high street)	10	250
Roads	Single 2-lane carriageway	25	625
Roads	Dual 1-lane	20	500
Roads	Dual 2-lane	30	750
Roads	Dual 3-lane	35	875
Boundaries	Banks	-4	-100
Boundaries	Ditch	-4	-100
Boundaries	Hedge	-4	-100
Boundaries	Wall, dry stone	-4	-100
Boundaries	Wall, mortared	-4	-100
Boundaries	No boundary	0	0
Boundaries	Stream	0	0
Boundaries	Fence	1	25
Building density	Building density as a proxy for urban resistance	0–20	0–500

4.3 Corridor design

To design wildlife corridors, we first used the Linkage Mapper toolbox (McRae and Kavanagh 2011) to build a network and map linkages (connections) between HCAs across the resistance surface. Linkages were calculated without restriction across the whole island and then restricted to three separate scenarios equivalent to Euclidean distances of (i) 250 m, (ii) 1000 m and (iii) 4000 m. These distance values were based on our review of known species movement capabilities (Appendix B) and are expected to represent a wide range of species. Linkage Mapper allows distances to be assessed based on either Euclidean (straight-line) distance, or cost-weighted distance. The latter can be described as the cumulative cost of moving through each cell, where the cost of a given cell is its resistance value multiplied by its size (i.e. 25 metres) (WHCWG 2010).

Corridors were designed excluding HCAs that occurred within built-up areas unless a focal species was considered to be an urban-dweller, in which case corridors were designed including HCAs occurring within built-up areas. This was based on the premise that HCAs occurring within built-up areas would be unsuitable for protection as they mainly consisted of gardens, buildings and other privately-owned features.

To identify linkage zones (sensu WHCWG 2010), normalised least-cost corridors were limited to cut-off values equivalent to a Euclidean corridor width of 100 metres across all scenarios, calculating the associated cost-weighted distance value based on the mean resistance values per metre in HCAs shown in Appendix C, Table C4. This relatively small value was used due to the fine-scale nature of the project. Similarities between corridor predictions were assessed between species to identify commonalities between them by overlaying them. Areas with greater overlap are therefore considered to have more importance for overall connectivity, and can be used as targets for conservation management.

Step 5 – Priorities for protection and restoration

We used the graph software Conefor v2.6 (Saura and Torné 2009) (www.conefor.org) to assess the importance of HCAs based on five indices related to their contribution to landscape connectivity. The metrics were (i) the integral index of connectivity (*dIIC*) (Pascual-Hortal and Saura 2006), (ii) the probability of connectivity (*dPC*) (Saura and Pascual-Hortal 2007) and the (iii) *intra*, (iv) *flux* and (v) *connector* fractions of the *dPC* metric (Saura and Rubio 2010; Baranyi et al. 2011). The *intra* fraction is a measure of intra-patch connectivity, whereas the *flux* and *connector* fractions are measures of inter-patch connectivity. Higher values of these indices indicate a greater contribution to landscape connectivity. *dIIC* is a binary metric, whereas *dPC* is probabilistic. To calculate these metrics, we used the HCAs as nodes, assigned node values based on their mean habitat suitability (calculated as the summed value of the inverse resistance surface within that polygon) and input the cost-weighted distances calculated previously in Linkage Mapper as distance measures of connectivity. Conefor requires a distance threshold to be set for each of the connectivity metrics used here. Therefore, we carried out runs at a single level equivalent to an intermediate Euclidean distance of 1000 metres (see Table C4) with a probability of 0.01 for PC indices. Other distances (250 and 4000 m) were not assessed due to processing time constraints. We requested delta outputs, and kept all other settings as defaults.

Pearson's correlation tests were used to assess similarities between the five different indices, and only those deemed to hold unique value were retained for further assessment. The HCAs for each species were then displayed according to each of the retained indices to provide a visual representation of the importance each HCA holds for connectivity. A cumulative network was then created by first standardising the indices for each focal species to between 0 and 1, and then summing the standardised values across the focal species. Higher values reflected greater priorities for connectivity. Overall prioritisation was then assessed based on landscape designations (see Table 4) and contribution to connectivity. Following the premise that areas that are currently unprotected are at greater risk of loss, these were prioritised above areas already within statutory designations. Therefore, we evaluated areas separately based on their existing designation.

Results

Step 1 – Focal species

The number of high accuracy records available for the 17 selected focal species ranged between 14 and 1,197 (Table 5), with greater numbers when geographic accuracy was not considered (Table 8). The distribution of these was also variable between species (Figure 3).

Step 2 – Species distribution models

Model performance

Final models performed well (Table D1 in Appendix D), with AUC_{test} values between 0.81 and < 1.00 (mean ± SD: 0.92 ± 0.06), and AUC_{diff} values between 0.00 and 0.14 (mean ± SD: 0.03 ± 0.04). The number of training occurrences in a cross-validation replicate ranged between four and 171, and test occurrences between one and nine. Final selected regularisation values ranged between 0.50 and 3.50, with the majority of models using the default value of 1.00.

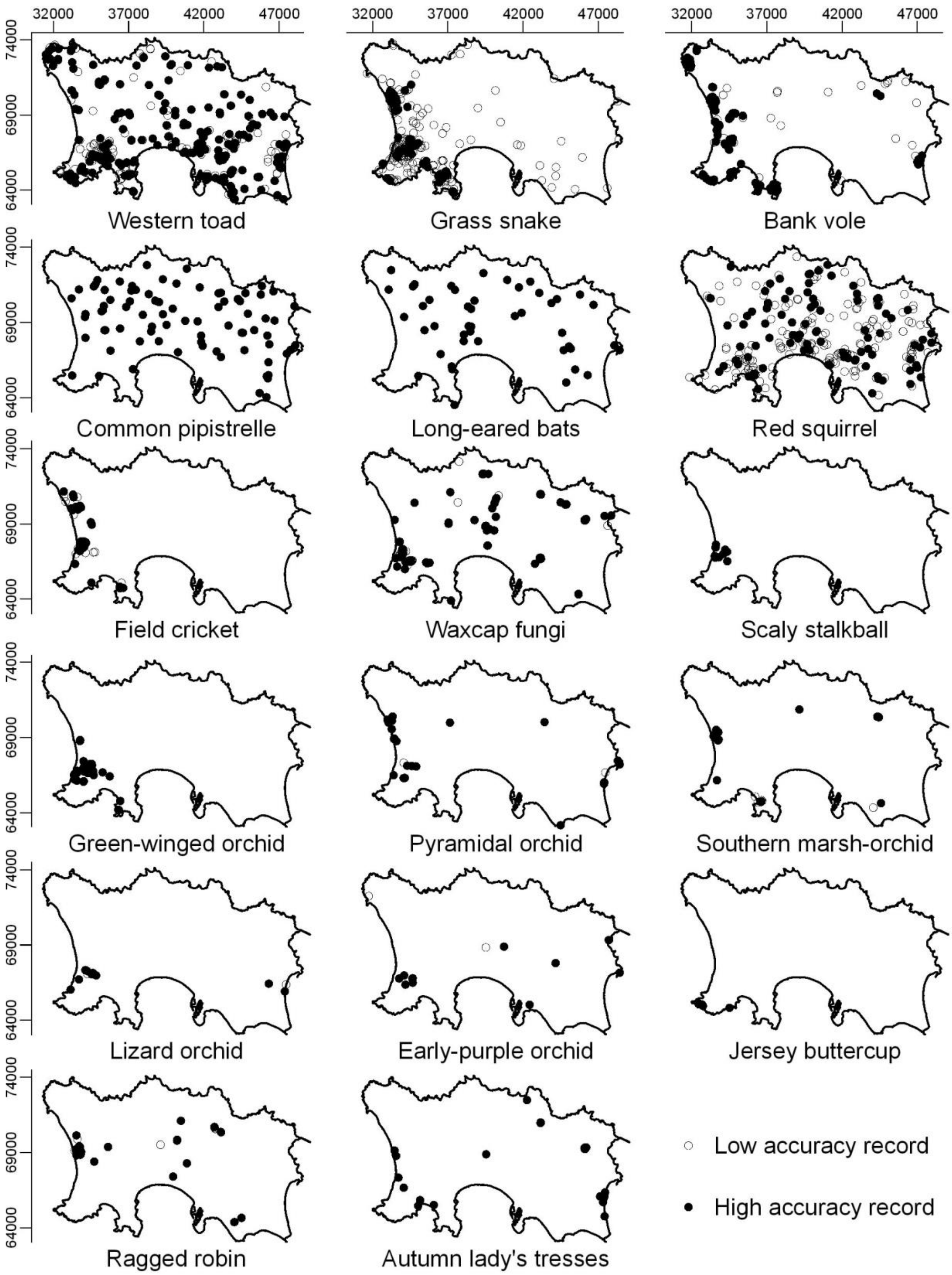


Figure 3 Occurrence records for 17 focal species between 2007 and 2017. Filled black circles show records of ≤ 10 m accuracy, hollow circles show records of > 10 m accuracy. Coordinates shown are in Jersey Transverse Mercator.

Variable importance

The variables tested for each species, those that were retained in the final models and their respective contributions to predictions of suitability are given in Appendix D (Table D2). Between two and nine variables were retained in final models, with a total of 37 unique variables tested across the species models and 31 retained across the final models. Landcover was the only variable retained for all final species models. The responses to the variables are shown in Appendix D and are discussed briefly for each species below.

- The toad was predicted to have preferences for gardens, scrub, wetland areas, unnatural bare ground, buildings, coastal heath and hottentot fig. The preference for unnatural bare ground is due to the occurrence of toads in urban environments (i.e. garden ponds) and the records therefore showing an association to paved areas when dominant on our landcover map at a 25 metre resolution. Hottentot fig is also not the true habitat, as the coastal areas in which it dominates are more representative of scrub habitat types. Toads were also associated to areas with higher building density due again to the presence of garden ponds, but at close and far distances from gardens when tested due to the occurrence of some populations in semi-natural environments such as coastal heathlands in the northwest of the island. For the same reason, distance to coastal heathland showed a similar response where areas close and far were favoured. Unsurprisingly, areas close to ponds and reservoirs were preferred.
- The grass snake was associated to dune grassland, dune heath, marram dominated dune and scrub landcover classes. Other variables indicated preferences for areas close to all scrub, coastal grassland, coastal heathland, dune grassland, ponds and reservoirs and known toad populations; the latter of which reflect the species' diet.
- The bank vole showed preference for multiple landcover classes reflecting its ability to occupy a variety of habitats. These were coastal grassland, coastal heath, dune grassland, marram dominated dune, mixed woodland, scrub and unimproved grassland. Their true habitat use and distribution is likely to be wider than the available data suggests (A. Hall, personal communication). Other variables influencing our suitability predictions suggested preferences for areas of lower building density, areas close to and far from all grassland, close to all scrub, close to boundaries, and of variable distance to woodland and verges. A lack of a clear pattern for some of these variables is again likely due to the species occupying a range of habitats across the island.
- Common pipistrelle bat roost locations were associated to unnatural bare ground, buildings and semi-improved grassland – consistent with many roost records occurring within urban and semi-urban buildings. They also showed a preference towards areas

closer to woodland, boundary features, historic buildings, major buildings and ponds and reservoirs.

- Long-eared bat roosts were also associated to buildings, but also wetland areas and appeared to favour more rural areas with a lower building density. They also showed preference for areas close to all types of bare ground (natural and unnatural), woodland, historic buildings, improved grassland and major buildings. However, the influences of distance to improved grassland, all bare ground and major buildings were minimal compared to a large influence of historic buildings (Table D2 in Appendix D).
- The red squirrel was associated to unnatural bare ground, gardens and mixed woodland landcover classes; though unnatural bare ground likely represents its presence in urban environments whilst foraging in gardens. It showed a preference for areas closer to woodland, gardens, mixed woodland, squirrel feeders and streams. It also appeared to prefer areas of at least low building density rather than no buildings, as well as areas closer to boundary features and roads. An affinity for roads may seem obscure, but this may be due to the presence of boundary features running parallel with roads in many instances. However, it may also be due to an observation bias, as they may be more easily observed alongside roads.
- The field cricket showed preferences for areas of natural bare ground (i.e. open dunes), bracken, dune grassland, marram dominated dunes and scrub. Areas with lower building density, and of close proximity to all grassland, all scrub, natural bare ground, coastal grassland and coastal heathland were favoured – reflecting the species known coastal range (Figure 3).
- Waxcap fungi were associated to dune grassland, marram dominated dune and semi-improved grassland landcover classes. There were also some indications of preferences for areas closer to natural bare ground, semi-improved grassland and unimproved grassland.
- The scaly stalkball fungus was predicted to most likely occur in dune grassland and marram dominated dune habitat, whilst avoiding open areas and boundaries but preferring areas close to grassland and dune marram. Of these variables, distance to dune marram appeared to have the greatest influence (Table D2 in Appendix D).
- The green-winged orchid showed preferences for coastal grassland, dune grassland and marram dominated dunes, in conjunction with being in close proximity to dune grassland and away from boundaries.
- The pyramidal orchid had higher suitability in areas with natural bare ground, dune grassland, marram dominated dunes and semi-improved grassland. Areas closer to

grassland, particularly dune grassland, were favoured, although the influence of semi-improved grassland was less clear and had very limited importance.

- The southern marsh-orchid showed strong associations to wetlands and dune grassland, but a weak association to areas more distant from woodland.
- The lizard orchid was associated to dune grassland and scrub. Low building density and areas close to or containing natural bare ground, dune grassland and scrub were favoured; though the association to scrub was weaker than other variables identified (Table D2 in Appendix D).
- The early-purple orchid was associated to areas of natural bare ground, dune grassland and unimproved grassland, with a preference for areas close to grassland.
- The Jersey buttercup was associated to bracken, coastal grassland and coastal heath; preferring areas close to all types of scrub and coastal grassland. However, a small sample size for training and testing (Table D1 in Appendix D) meant that only simple responses could be calculated and should be perceived with caution.
- Ragged robin showed preferences for marram dominated dune, tall ruderal habitats and wetlands. It was also associated to areas closer to all scrub, streams and wetlands, but showed a mixed response to distance to all woodland.
- Autumn lady's-tresses was associated to areas of natural bare ground, dune grassland, semi-improved and unimproved grassland. Areas closer to bare ground, cemeteries, coniferous woodland, streams and dune heathland were preferred, along with areas further away from all woodland combined. Associations to coastal grassland included those areas close and distant to the habitat type.

Distribution of suitable areas

Suitability predictions for each focal species are shown in Figure 4 for MaxEnt outputs, and Figure 5 after applying a binary threshold (maxSSS) to the output. Areas predicted to have high suitability were skewed towards coastal regions, particularly in the west and south-west of the island for several species: green-winged orchids, pyramidal orchids, field crickets, lizard orchids, grass snakes, early-purple orchids, Jersey buttercups and scaly stalkballs.

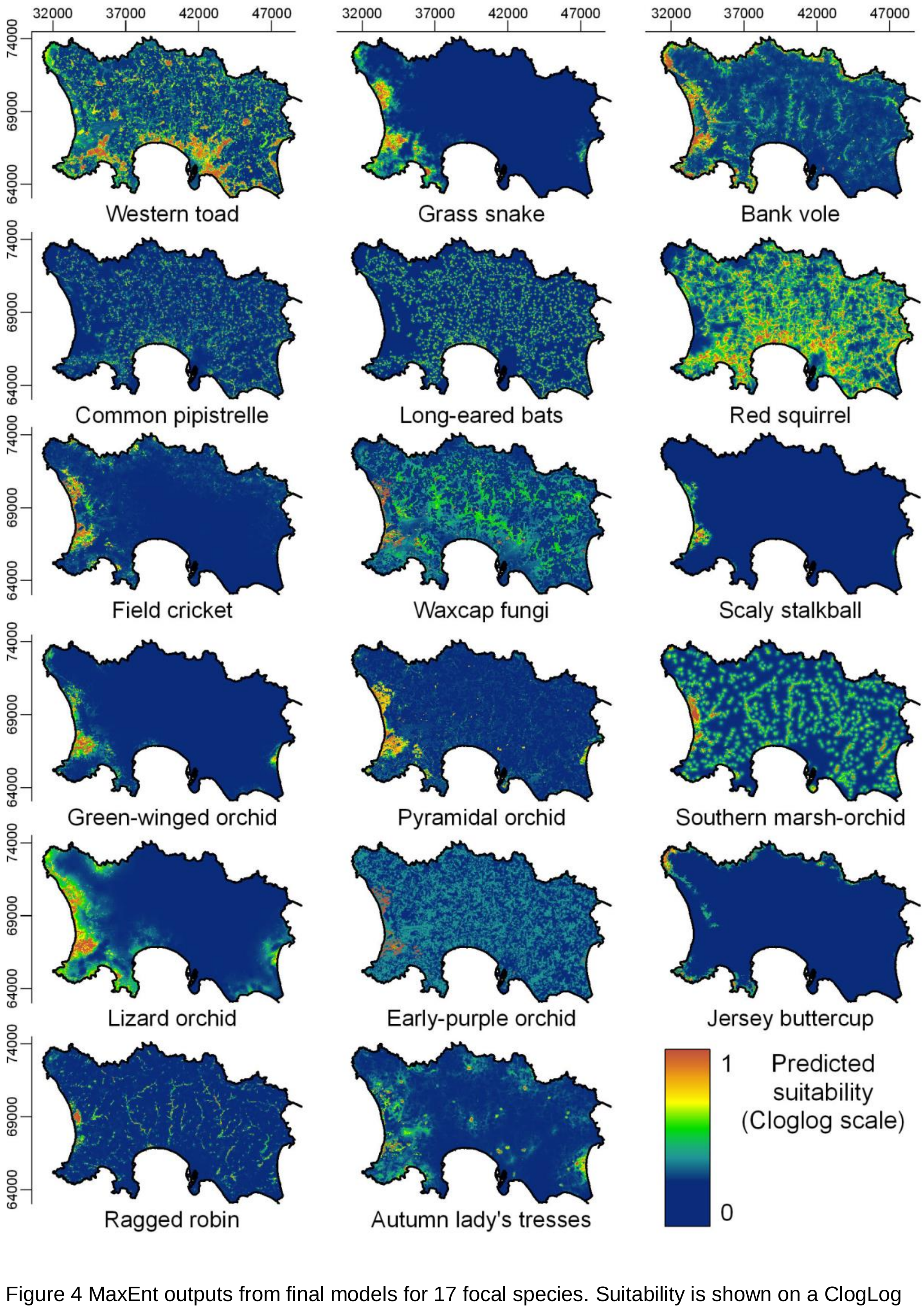


Figure 4 MaxEnt outputs from final models for 17 focal species. Suitability is shown on a ClogLog scale of 0 to 1, with higher values indicating greater predicted suitability for the species modelled. Coordinates shown are in Jersey Transverse Mercator.

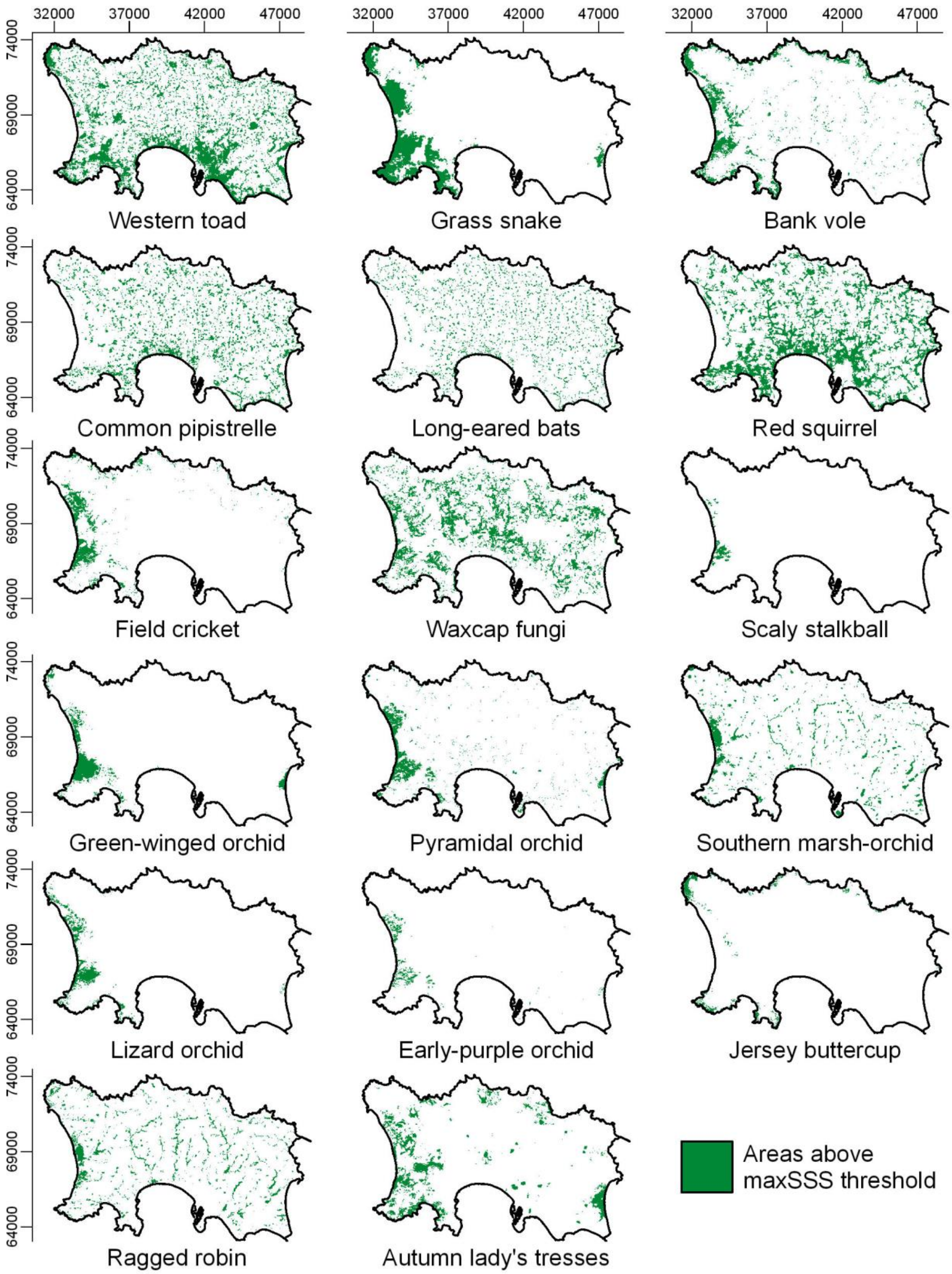


Figure 5 MaxEnt outputs from final models for 17 focal species after applying a binary threshold which maximises the sum of sensitivity and specificity (maxSSS). Coordinates shown are in Jersey Transverse Mercator.

Step 3 – Habitat concentration areas (HCAs)

HCA reduction

The patches identified with the Modified Proximity Index that were subsequently removed were an average of 0.116 ha in size (range: 0.063–1.688, SD: 0.105). Though some of the less mobile species present in the island can survive in areas this small (Appendix B), it is unlikely they contribute to a functional metapopulation if heavily isolated. The removal of these patches resulted in an average decrease of 38.11 ha (range: 2.13–100.00, SD: 32.53) in HCAs across the 17 focal species. Following the further removal of unsuitable landcover (e.g. roads), HCAs including built-up areas covered a total area of 5,060.8 ha. This is equivalent to 42.1% of the island, which is itself 12,028.7 ha in area (Table 10).

Performance of landscape designations

Our results suggest that existing evaluations of important biodiversity areas and other statutory designations do provide areas of valuable habitat. This includes 91.6% of ecological SSIs, 40.4% of geological SSIs, 69.1% of pSSIs, 78.3% of the Jersey National Park, 79.7% of Environmentally Sensitive Areas[4] and 34.7% of the Green Zone being included in HCAs. However, only a small proportion of HCAs fall within these designations, with 8.4% of HCAs occurring in ecological SSIs, 0.6% in geological SSIs, 0.8% in pSSIs, 29.8% in the JNP, 44.0% in ESAs and 57.7% in the Green Zone. At the species level, each species' HCAs covered between 0.8 and 15.0% of the island, and the amount of any species HCAs within each of the designations discussed varied between 0.1 and 62.6% for ecological SSIs, 0.0 and 2.9% for geological SSIs, 0.1 and 3.7% for pSSIs, 7.3 and 99.3% for the JNP, between 14.9 and 99.5% for ESAs and between 0.3 and 74.9% for the Green Zone (Table 10).

Inter-species HCA overlap

The individual HCAs for each species showed varying degrees of overlap with one another when including built-up areas, ranging between 0.0 and 100.0% (Table E1 in Appendix E). Similar levels of overlap were also seen when excluding built-up areas (not shown). The highest levels of HCA overlap were between the following species combinations:

- early-purple orchid and
    - green-winged orchid
    - pyramidal orchid

[4] Note that the Environmentally Sensitive Areas include the majority (88.54%) of the Jersey National Park.

    - field cricket
    - lizard orchid
    - waxcap fungi
    - bank vole
    - grass snake
    - autumn lady’s-tresses
- scaly stalkball and
    - green-winged orchid
    - pyramidal orchid
    - field cricket
    - bank vole
    - grass snake
- green-winged orchid and grass snake
- pyramidal orchid and grass snake
- lizard orchid and
    - bank vole
    - grass snake
- long-eared bat and common pipistrelle bat roosts
- Jersey buttercup and bank vole.

This suggests that some species may be suitable umbrella species for others in the analysis. These overlaps were primarily associated to species predicted to have high suitability along the west coast (Figure 5).

HCAs in built-up areas

Five species had more than 10% of their HCA coverage within built-up areas (Table 11) and were subsequently assessed separately to all other focal species which had HCAs evaluated without built-up areas. These five urban-dwelling species were the toad, red squirrel, autumn lady’s-tresses, common pipistrelle and long-eared bat roosts. The hotspot maps generated from the species’ HCAs (Figure 7) highlight a greater degree of HCA overlap in the west and south-west of the island, followed by areas in the east of the island and within the wooded valleys. These areas are therefore priorities for conservation.

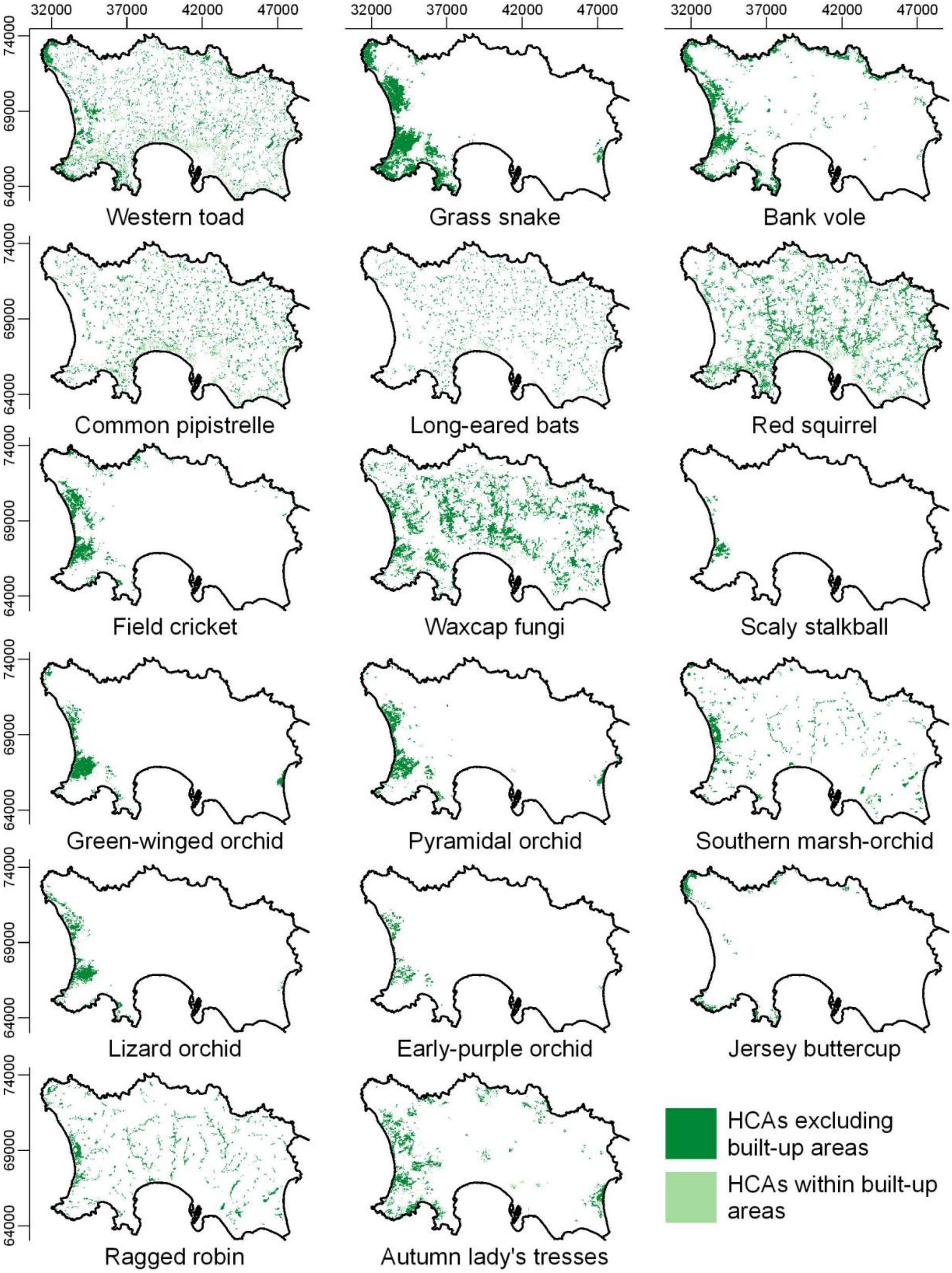


Figure 6 Habitat Concentration Areas (HCAs) for 17 focal species excluding built-up areas (dark green) and additional HCAs within built-up areas (light green) following removal of unsuitable habitats (e.g. roads) and small isolated patches. Coordinates shown are in Jersey Transverse Mercator.

Table 10 Coverage of each species' Habitat Concentration Areas (HCAs) prediction including those occurring within built-up areas. Percentages are shown as the percentage of island cover, the percentage of each designation (see Table 4) containing HCAs for each focal species, the percentage of each focal species' HCAs falling within a given designation, and overall when combining HCAs across all focal species including and excluding built-up areas. The designations are (i) designated ecological Sites of Special Interest (eSSIs), (ii) designated geological Sites of Special Interest (gSSIs), (iii) combined designated ecological and geological Sites of Special Interest (SSIs), (iv) proposed ecological Sites of Special Interest (pSSIs), (v) the Jersey National Park (JNP), (vi) Environmentally Sensitive Areas (ESAs) and (vii) the Green Zone (GZ).

Species	Area (ha)	% of island	% of designation containing HCAs							% of HCAs falling within designation						
			eSSI	gSSI	SSI	pSSI	JNP	ESA	GZ	eSSI	gSSI	SSIs	pSSI	JNP	ESA	GZ
Western toad	1411.2	11.7	37.6	10.2	33.7	9.9	22.7	21.1	7.8	12.3	0.5	12.5	0.4	30.9	41.7	46.5
Grass snake	1077.8	9.0	68.2	2.5	60.4	6.2	39.8	30.2	3.1	29.3	0.2	29.4	0.3	71.1	78.4	24.1
Bank vole	920.1	7.6	60.5	28.0	55.9	37.8	41.4	30.9	1.4	30.5	2.3	31.8	2.4	86.5	93.9	12.9
Common pipistrelle bat	1027.3	8.5	0.3	0.2	0.3	1.8	3.9	6.2	7.9	0.1	0.0	0.1	0.1	7.3	16.8	65.0
Long-eared bats	565.3	4.7	0.2	0.1	0.2	0.7	2.2	3.0	4.9	0.2	0.0	0.2	0.1	7.6	14.9	73.0
Red squirrel	1763.0	14.7	2.2	1.0	2.1	8.4	12.3	20.9	15.1	0.6	0.0	0.6	0.3	13.4	33.1	71.9
Field cricket	532.1	4.4	30.9	5.1	27.9	8.7	24.4	17.5	0.7	26.9	0.7	27.5	1.0	88.3	91.9	10.4
Waxcap fungi	1799.6	15.0	22.9	1.0	20.3	38.6	20.2	29.4	16.0	5.9	0.0	5.9	1.3	21.6	45.7	74.9
Scaly stalkball	92.1	0.8	12.4	0.0	11.0	5.8	4.8	3.3	0.0	62.6	0.0	62.6	3.7	99.3	99.5	0.3
Green-winged orchid	379.1	3.2	35.7	0.9	31.5	6.2	18.1	12.7	0.3	43.6	0.2	43.6	1.0	91.7	93.8	5.7
Pyramidal orchid	439.0	3.6	29.4	1.8	26.1	6.5	19.3	13.7	0.6	31.0	0.3	31.2	0.9	84.7	87.1	11.6
Southern marsh-orchid	459.7	3.8	21.3	0.9	19.0	15.3	11.4	12.3	2.8	21.5	0.1	21.6	1.9	47.7	74.5	50.3
Lizard orchid	313.9	2.6	31.4	0.8	27.8	2.0	15.6	10.9	0.1	46.3	0.2	46.4	0.4	95.7	96.7	3.4
Early-purple orchid	150.0	1.2	12.4	0.0	10.9	1.2	6.9	5.1	0.2	38.3	0.0	38.3	0.5	88.9	94.2	10.6
Jersey buttercup	193.0	1.6	21.8	7.4	20.0	1.9	9.5	6.5	0.1	52.3	2.9	54.5	0.6	94.5	94.9	4.9
Ragged robin	541.0	4.5	20.1	0.5	17.8	16.8	10.1	14.1	4.0	17.2	0.1	17.3	1.8	35.8	73.0	62.3
Autumn lady's-tresses	734.2	6.1	27.0	15.2	24.3	3.7	18.9	13.8	2.8	17.0	1.6	17.4	0.3	49.6	52.7	31.9
Total (incl. built-up)	5060.8	42.1	91.6	40.4	84.2	69.1	78.3	79.7	34.7	8.4	0.6	8.7	0.8	29.8	44.0	57.7
Total (excl. built-up)	4506.8	37.5	91.6	40.4	84.2	69.1	78.3	79.6	34.7	9.4	0.7	9.8	0.9	33.4	49.4	64.8

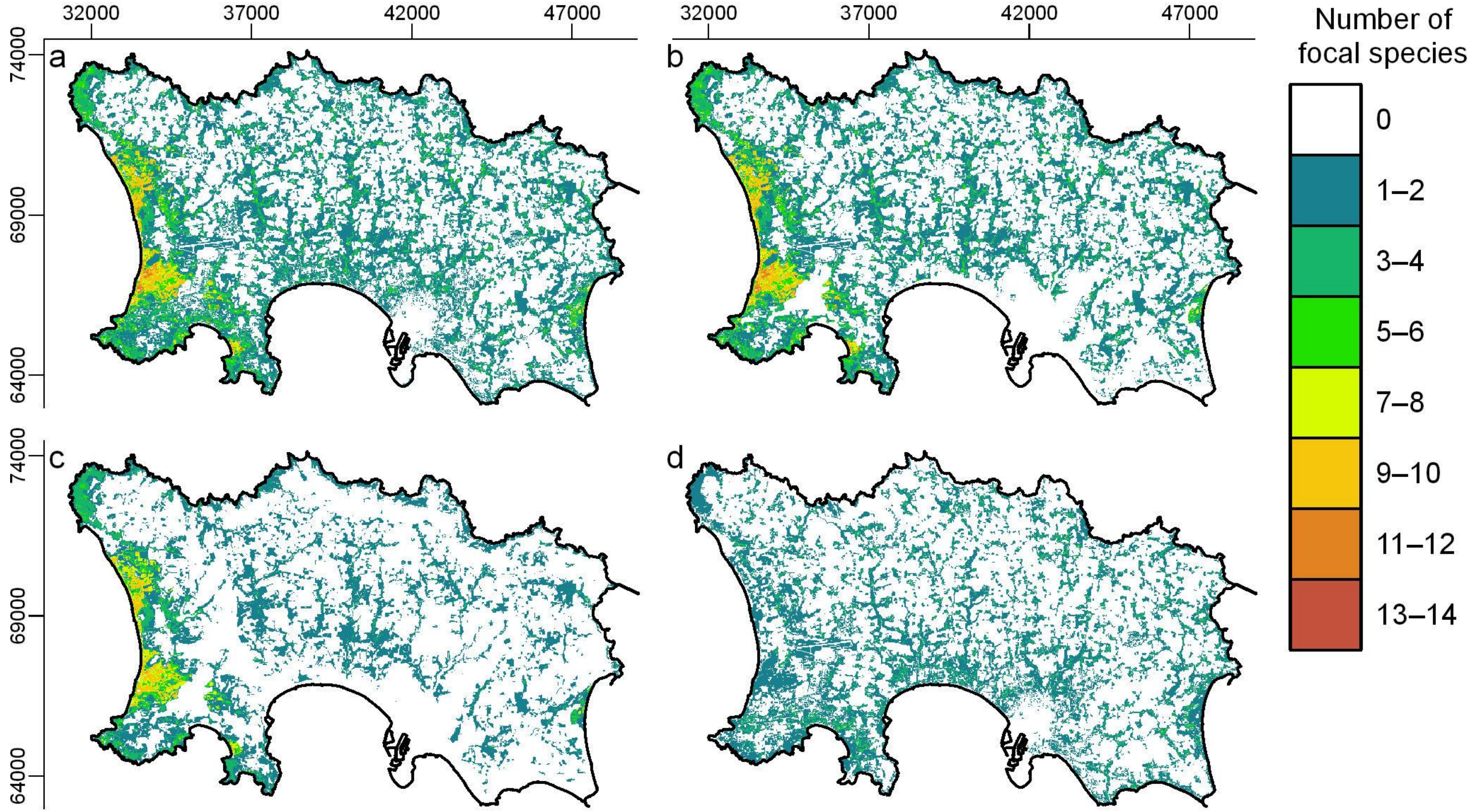


Figure 7 Hotspot maps showing (a) the overlap of all 17 focal species Habitat Concentration Areas (HCAs) including HCAs that occur within built-up areas, (b) the overlap of all 17 focal species HCAs with built-up areas removed, (c) the overlap of 12 focal species excluding built-up areas and urban-dwellers and (d) the overlap of five urban-dwelling focal species including built-up areas. Colours indicate the number of focal species' HCAs overlapping in that area. The map is shown at a grid cell resolution of 25 metres. Coordinates shown are in Jersey Transverse Mercator.

Table 11 Area and proportion of each species Habitat Concentration Area prediction falling within built-up areas. Species assessed separately due to large built-up area components are shown in **bold**.

Species	Area (ha)	% HCAs
Western toad	**312.1**	**22.1**
Grass snake	45.6	4.2
Bank vole	0.9	0.1
Common pipistrelle bat	**282.9**	**27.5**
Long-eared bats	**108.5**	**19.2**
Red squirrel	**253.9**	**14.4**
Field cricket	0.8	0.2
Waxcap fungi	54.4	3.0
Scaly stalkball	0.0	0.0
Green-winged orchid	6.4	1.7
Pyramidal orchid	10.4	2.4
Southern marsh-orchid	7.6	1.6
Lizard orchid	0.5	0.1
Early-purple orchid	0.2	0.1
Jersey buttercup	0.0	0.0
Ragged robin	9.6	1.8
Autumn lady's-tresses	**77.7**	**10.6**

HCA Validation

Overlay of raw records

Of the 98 CWL species tested, 73.43% of known species occurrence records (7,426 out of 10,113) fell within the HCAs. Removal of the focal species (which may bias the outcomes) leads to a decrease to 66.55% (4,631 out of 6,959). When considering the geographic accuracy of records and of mapping layers, we may expect there to be some deviations from this. Indeed, though a number of records fell outside of the predicted priority areas, on average records were 6.04 m (± 16.72 SD; median=0.00; n=10,113) from HCAs including focal species[5], and 7.97 m (± 18.39 SD; median=0.00; n=6,959) for the 83 species without; indicating that most known occurrences fall close to, or within the HCAs. By comparison to these values, the HCAs cover 42.07% of the island; suggesting that the HCAs provide good coverage for protected species and not just in proportion to the area of land they cover. Similar patterns were seen in unprotected fungi species, for which 97.14% of occurrences fell within HCAs, at an average distance of 0.18 m (SD: 1.11). The outputs of these tests can be found in Figures E1–7 in Appendix E.

Species expert-identified areas

Several areas were identified by the Société Jersiaise Ornithology Section that are considered to be of high importance for local bird populations (Table E2 in Appendix E). Visual inspection indicated a high level of overlap between these areas and the HCAs.

[5] Note that these calculations do not include unprotected focal species; waxcap fungi, the scaly stalkball or ragged robin.

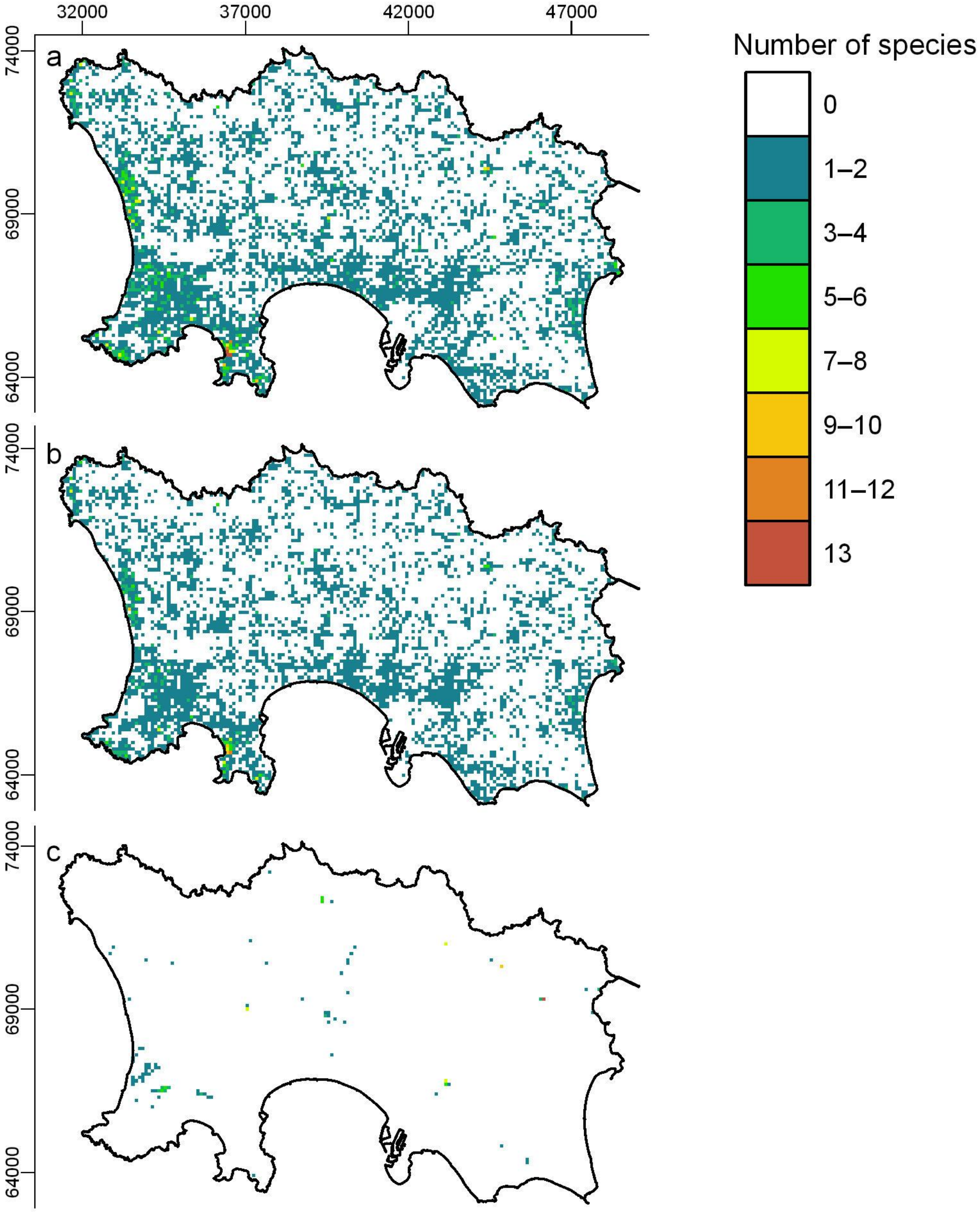


Figure 8 Hotspot maps showing the number of species with occurrence records (2007–2017) within each 100 metre grid cell resolution for (a) 98 species protected or proposed for protection under the Conservation of Wildlife Laws (CWL) 2000 and 2009, (b) 83 species excluding those analysed as focal species and (c) 26 fungi species. Colours indicate the number of species occurring within a given 100 m grid cell. Coordinates shown are in Jersey Transverse Mercator.

Step 4 – Wildlife corridors

The resistance surfaces generated for each focal species are shown in Figure 9, and demonstrate the higher level of resistance encountered from Jersey's transportation network and built-up areas for many species.

Outputs showing least-cost paths and least-cost corridors are shown for each focal species in Appendix F. General patterns indicate limited connectivity between populations when considering a dispersal distance of 250 metres, but with connectivity rapidly increasing as dispersal ability improves. In some cases, however, there is little increase in connectivity beyond a dispersal distance of 1000 metres due to the proximity at which many HCAs occur.

Overlapping corridors across species show similarities in the west of the island when assessing all 17 focal species (excluding built-up HCAs) (Figure 10) and 12 focal species (excluding built-up HCAs) (Figure 11) following the removal of five urban-dwelling focal species. The patterns for those five urban-dwelling focal species when including corridors between HCAs within built-up areas shows a more widespread pattern of corridor overlap (Figure 12).

Though the corridors shown below and in Appendix F are restricted by Euclidean (straight-line) distance, the cost-weighted distance associated with these least-cost paths and corridors is highly variable, meaning that many may be unsuitable for species restricted by barriers in the landscape to travel through. Areas of restricted movement are also shown as narrow pinch points in Figures 10–12, where corridors are narrow due to high costs associated to the landscape surrounding least-cost paths. These pinch points can be alleviated through work to improve landscape suitability for wildlife in these areas.

At a dispersal distance of 250 metres, corridor priorities resulting from the overlap of all 17 focal species were mostly in the west (Figure 10a), running:

(1) from Ouaisné (CA B3: South Coast Urban Coastal Plain) northeast to Travers Farm, and throughout much of the peninsula including Portelet common SSI (CA A2: South West Heathland) and northeast to the coastal woodland north of Noirmont Manor,

(2) from Beauport (CA A2: South West Heathland) northwards to La Marquanderie and Les Creux Millennium Country Park (CA D3: St Brelade Valleys),

(3) from the west end of St Brelade's bay, following the escarpment situated behind the seafront developments eastwards and then south to Ouaisné (CA C2: South Coast Escarpment),

(4) north from midbay car park (St Brelade's bay), crossing La Route des Genets near the synagogue and carrying on northwards through Reg's gardens, Jersey Lavender, part of the Railway Walk and Pont Marquet before following the remaining woodland up to the southeastern corner of the airport (CA D3: St Brelade Valleys),

(5) along the southern edge of the airport connecting through Les Ormes and Creepy Valley in to Les Blanches Banques,

(6) along the railway walk and surrounding woodland from St Aubin, northwest to Pont Marquet (joining corridor 4) (CA D3: St Brelade Valleys),

(7) along the west coast from the southwest corner (La Corbière) northward, including through Les Blanches Banques (CA B4: Quennevais Dunes Coastal Plain), Simon Sand, around St Ouen's pond and up through Les Mielles Nature Reserve to La Saline (CA B5: St Ouen's Bay Coastal Plain), and along the escarpment behind the bay encompassing Le Val de La Mare (CA C3: St Ouen's Bay Escarpment and Valleys),

(8) from the area of La Saline and the northern end of Chemin du Moulin/St Ouen's bay escarpment, north through Les Pres D'Auvergne then northwest towards and in to the western edge of Les Landes de l'Est (CA C3: St Ouen's Bay Escarpment and Valleys),

(9) from Les Pres D'Auvergne, north along Mont Huelin and then northeast following Le Mont, west along Rue du Sud before heading northeast along Rue des Pallières then up to the coast just east of Plémont,

(10) from Les Pres D'Auvergne, eastwards along Mont Pinel and Route du Marais towards St Ouen's village,

(11) from Grève de Lecq, southwest through La Ville Bagot and Leoville until connecting with the woodland along Route du Marais,

(12) throughout the island's wooded valleys (CAs D1–5: Enclosed Valleys) and other linear vegetation features including along road networks,

(13) in to parts of Royal Jersey Golf Club (CA B1: Grouville Coastal Plain).

Results from the overlap of 12 species (excluding urban-dwellers) showed similar results but with corridors being less widespread (Figure 11a). In comparison, corridor priorities from the five urban-dwelling species were widely distributed, including many urban areas aside from St Helier and with less relation to the wooded valleys (Figure 12a).

Increasing the dispersal distance to 1000 metres showed a similar, but more connected corridor network than at 250 metres and with a higher degree of overlap. The strongest corridors in the 17-species scenario ran from the southwest in La Corbière eastwards to Les Creux, Beauport and La Marquanderie before heading further east across St Brelade's bay south coast escarpment to Le Mont Sohier. From there, corridors ran north to the southeastern corner of the airport, as described above for route 4. Corridors then run along the southern edge of the airport before following the St Ouen's bay escarpment northwards to La Saline and Route du Marais. From there, corridors heading northwest and northeast to Landes (de l'Est) and Grève de Lecq respectively follow similar routes as described above for corridors 8 and 11. Strong support for corridors was also seen around Ouaisné and Portelet (as described for corridor 1 above). In addition, corridors are well developed along much of the western coastal plains, throughout the island's enclosed wooded valleys and to the east in to Gorey. The 12-species scenario shows similar but less widespread corridors, which include portions of the north coast. For the five urban-dwellers, corridors become more widely distributed than at 250 metres but with less definitive patterns.

Further increases in dispersal distance to 4000 meters for all species-scenarios are similar to those described for 1000 metres, but are more widespread and with less defined corridors. Finally, unrestricted corridors for 17 species produce a greater spread of corridors further inland, including theoretical routes from the west to Grouville in the east. Corridors also become more evident around St Aubin and Beaumont, St John's Manor, and between Sion and Trinity Manor. Again, the 12-species scenario is similar but less widespread, and the urban-dweller scenario is more widely distributed than at smaller dispersal distances with less clear patterns. It is unsurprising that wildlife corridor opportunities for urban-dwelling species appear to be less restrictive.

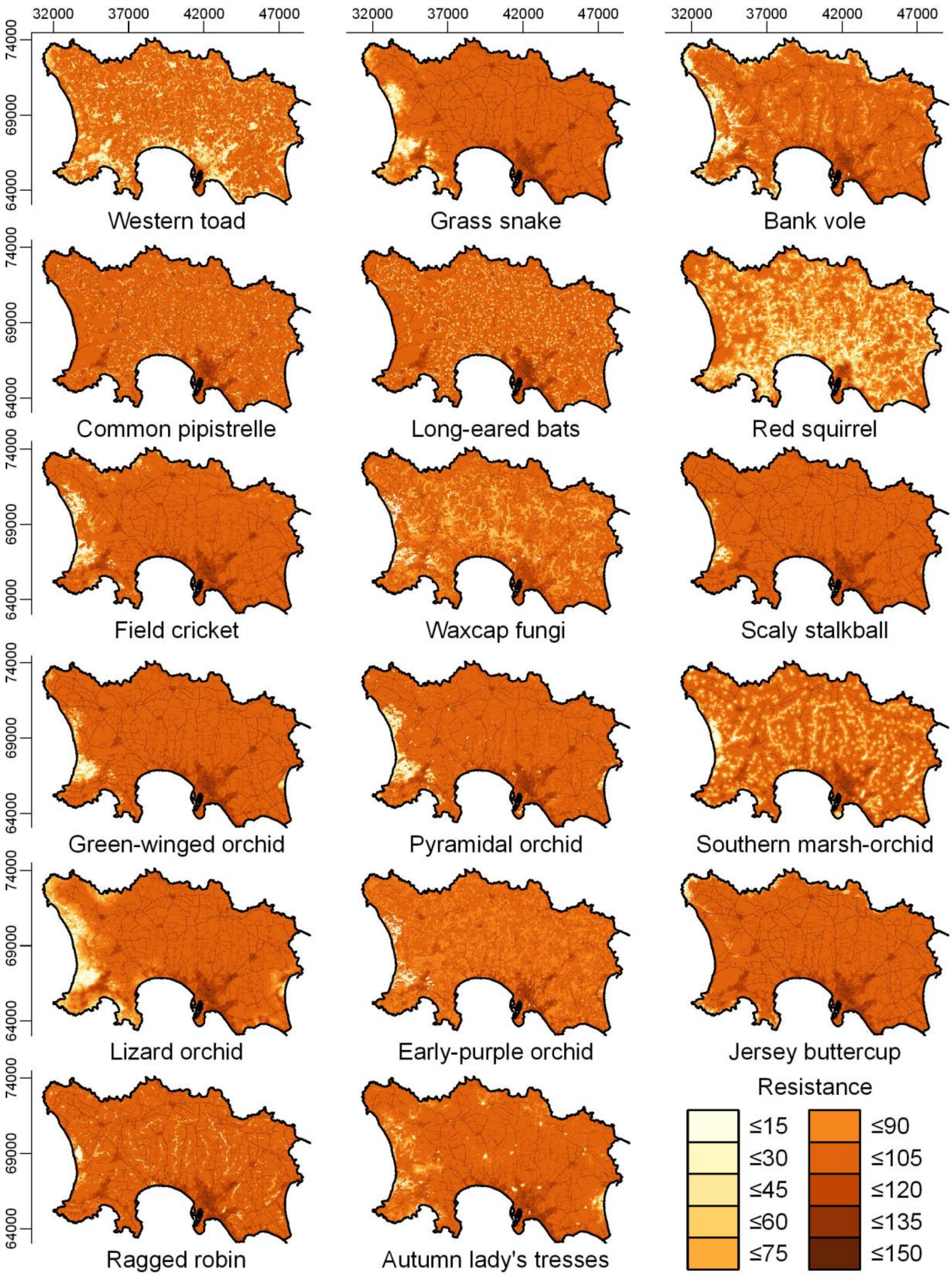


Figure 9 Resistance surfaces for 17 focal species calculated from a linear negative transformation of the MaxEnt output and resistance values for roads, boundaries and building density. Darker colours indicate higher resistance to movement. Coordinates shown are in Jersey Transverse Mercator.

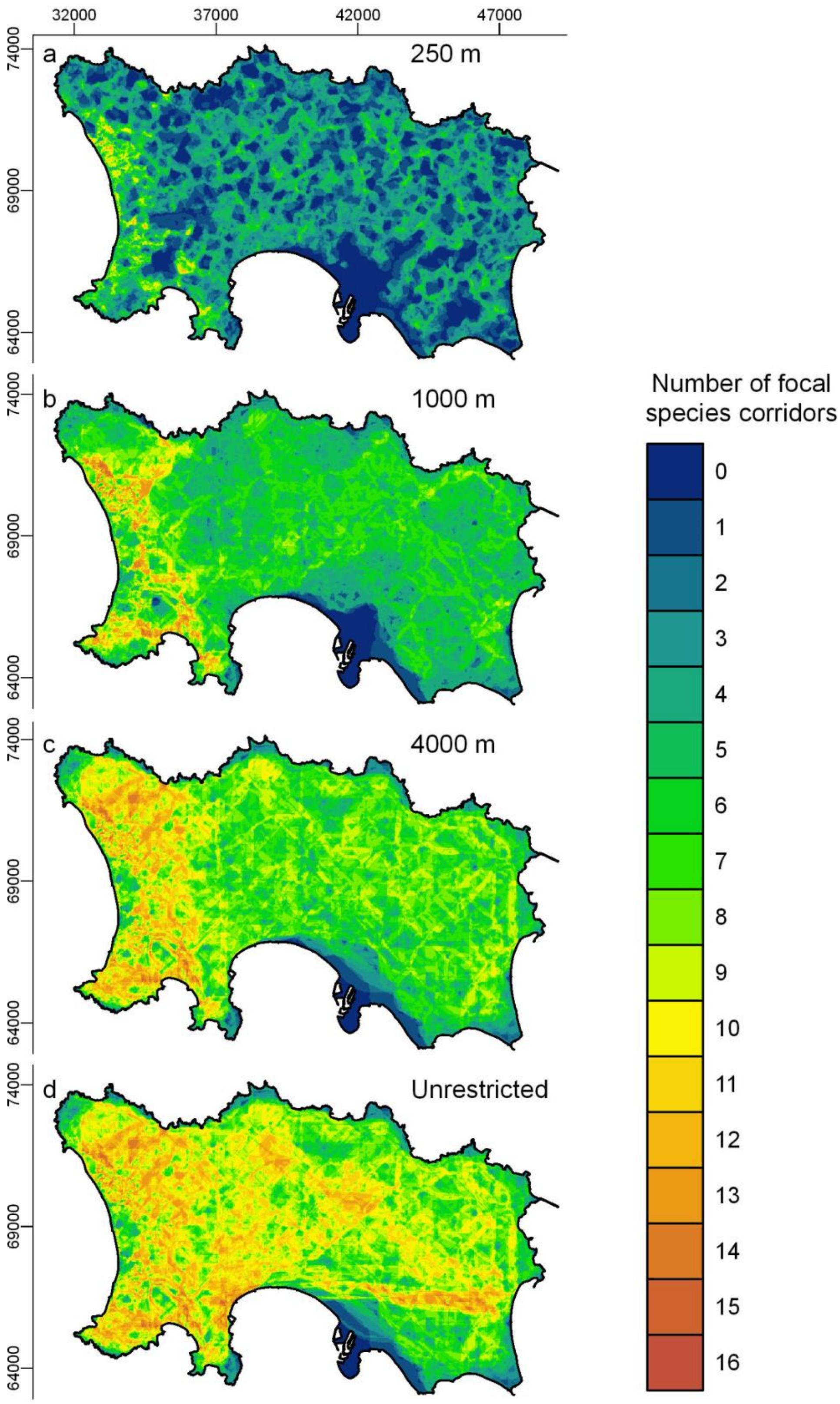


Figure 10 Overlapped species least-cost corridors of cost-weighted width equivalent to 100 metres for 17 focal species excluding HCAs from built-up areas. Corridors were restricted to maximum Euclidean distances of (a) 250 m, (b) 1000 m, (c) 4000 m or (d) unrestricted by Euclidean distance. Warmer colours indicate a larger number of focal species' corridors occurring in that area. Coordinates shown are in Jersey Transverse Mercator.

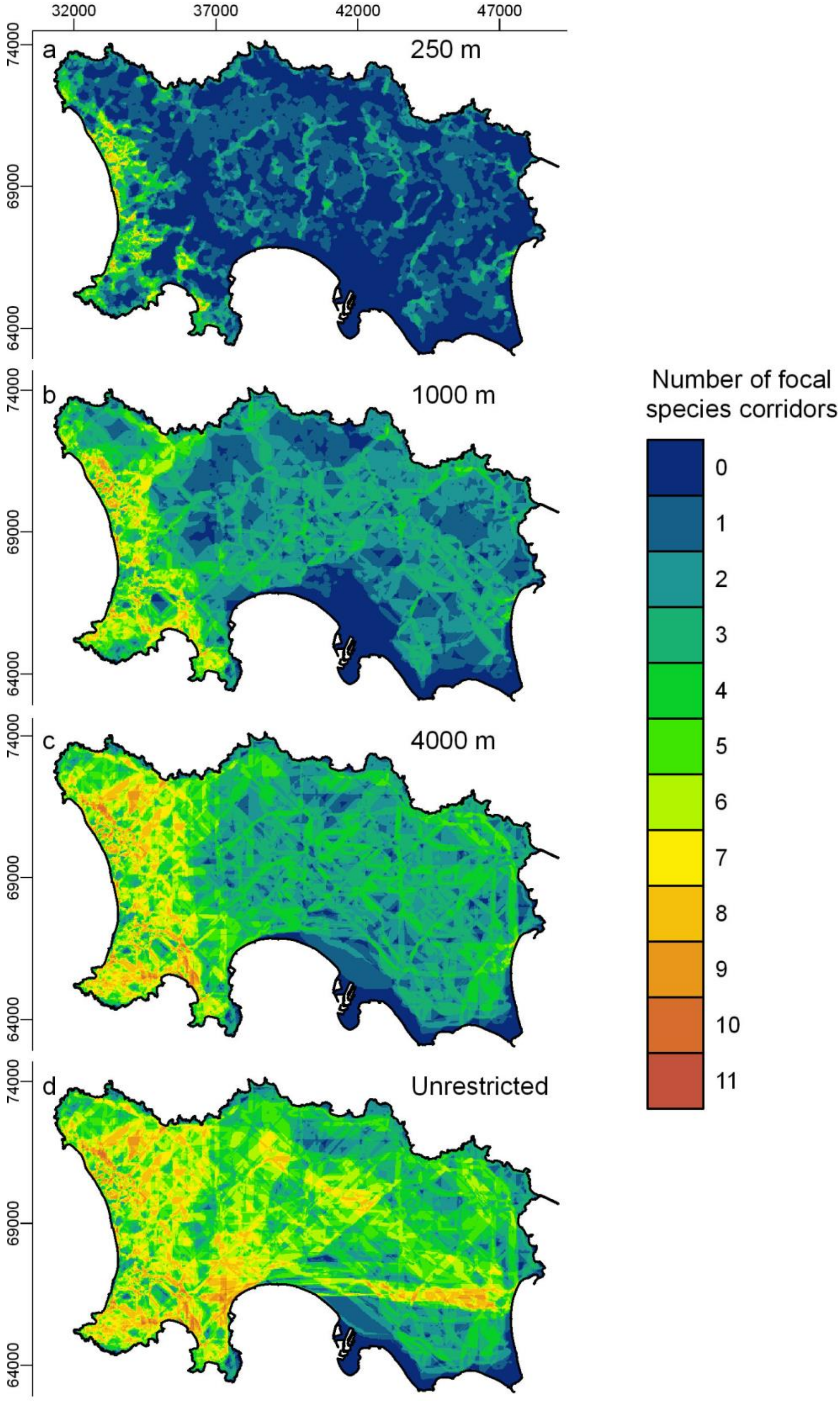


Figure 11 Overlapped species least-cost corridors of cost-weighted width equivalent to 100 metres for 12 focal species excluding HCAs from built-up areas and focal species with ≥ 10% of HCA coverage within built-up areas. Corridors were restricted to maximum Euclidean distances of (a) 250 m, (b) 1000 m, (c) 4000 m or (d) unrestricted by Euclidean distance. Warmer colours indicate a larger number of focal species' corridors occurring in that area. Coordinates shown are in Jersey Transverse Mercator.

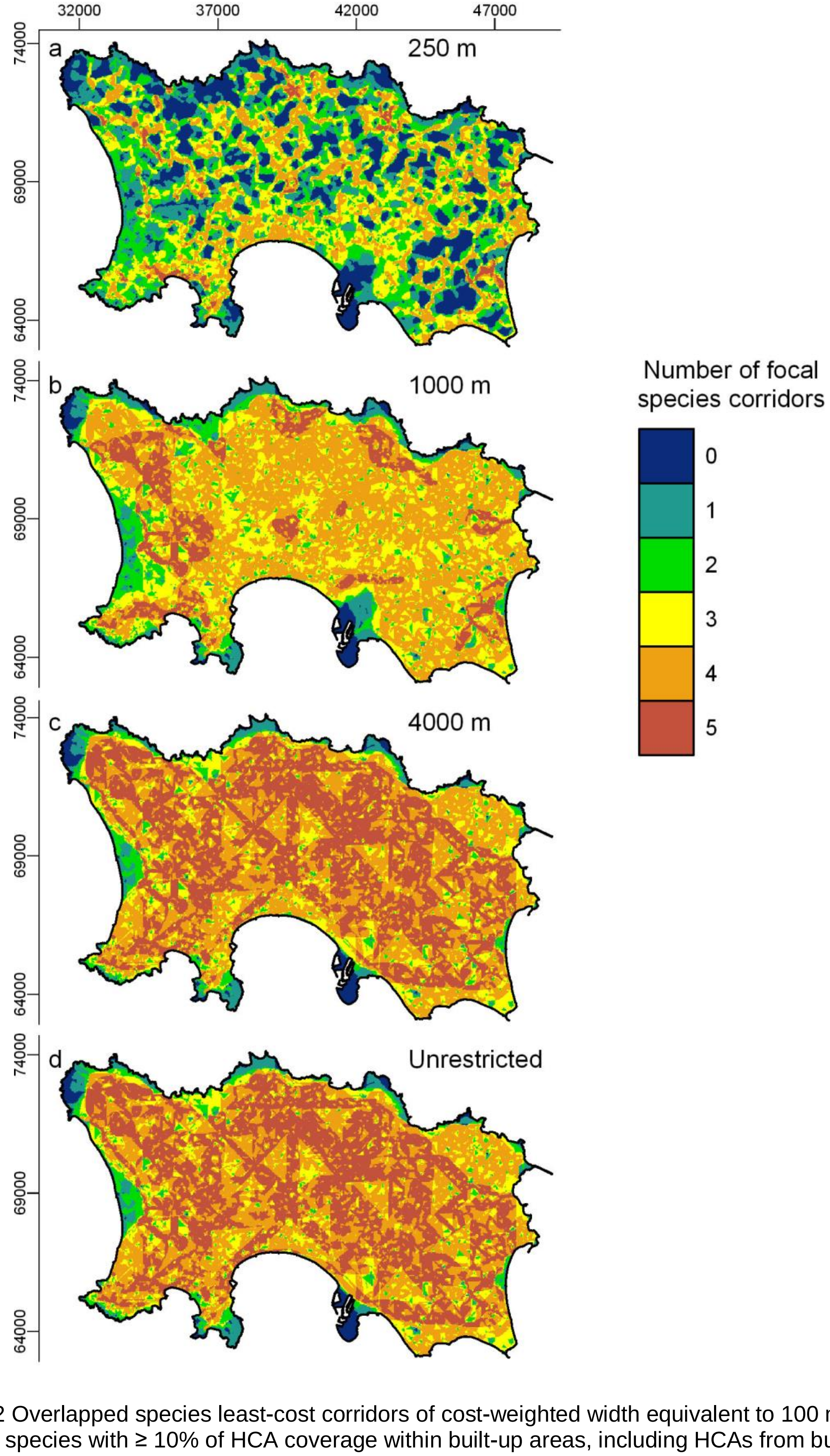


Figure 12 Overlapped species least-cost corridors of cost-weighted width equivalent to 100 metres for five focal species with ≥ 10% of HCA coverage within built-up areas, including HCAs from built-up areas. Corridors were restricted to maximum Euclidean distances of (a) 250 m, (b) 1000 m, (c) 4000 m or (d) unrestricted by Euclidean distance. Warmer colours indicate a larger number of focal species' corridors occurring in that area. Coordinates shown are in Jersey Transverse Mercator.

Overall priorities for connecting non-urban HCAs based on corridor overlap are shown in Figure 13. These are labelled according to the descriptions of these corridors, which broadly speaking, run:

A. From La Corbière, eastward to St Brelade's bay
B. From west to east following the escarpment behind St Brelade's bay seafront (eastern portion of CA C2: South Coast Urban Escarpment)
C. Between Le Mont Sohier, Ouaisné, Portelet and Noirmont; linking these areas
D. North from St Brelade's bay (midbay carpark) to the southeastern corner of the airport (including northern part of CA D3: St Brelade Enclosed Valley)
E. Along the southern edge of the airport through Les Ormes Golf Club and on to Les Blanches Banques
F. From above Pont Marquet (Maison St Brelade residential home), going west / northwest across the top of Les Quennevais and through Creepy Valley on to Les Blanches Banques
G. North along St Ouen's bay escarpment and valleys (CA C3) and in parallel along St Ouen's bay coastal plain (CA B5) from Les Blanches Banques (CA B4: Quennevais Dunes Coastal Plain) to La Saline and Les Pres D'Auvergne
H. From the wooded area along Route du Marais, south to La Ville au Bas
I. Eastwards from Les Pres D'Auvergne to Route du Marais
J. Northwest from Les Pres D'Auvergne to Les Landes de l'Est (northern portion of CA C3: St Ouen's Bay Escarpment)
K. From the wooded area along Route du Marais, northeast to Grève de Lecq and then west along the coast to Plémont (incorporating the western portion of CA D4: North Coast Valleys)
L. Throughout the enclosed wooded valleys (CAs D1–5)
M. Between Rozel woods (CA D5: St Martin's Valleys) and Jersey Zoo (at the north-western tip of the woodland running from St Helier to Trinity) (CA D2: Eastern Valleys)
N. Through Grouville Marsh and parts of Royal Jersey Golf Club (CA B1: Grouville Coastal Plain)

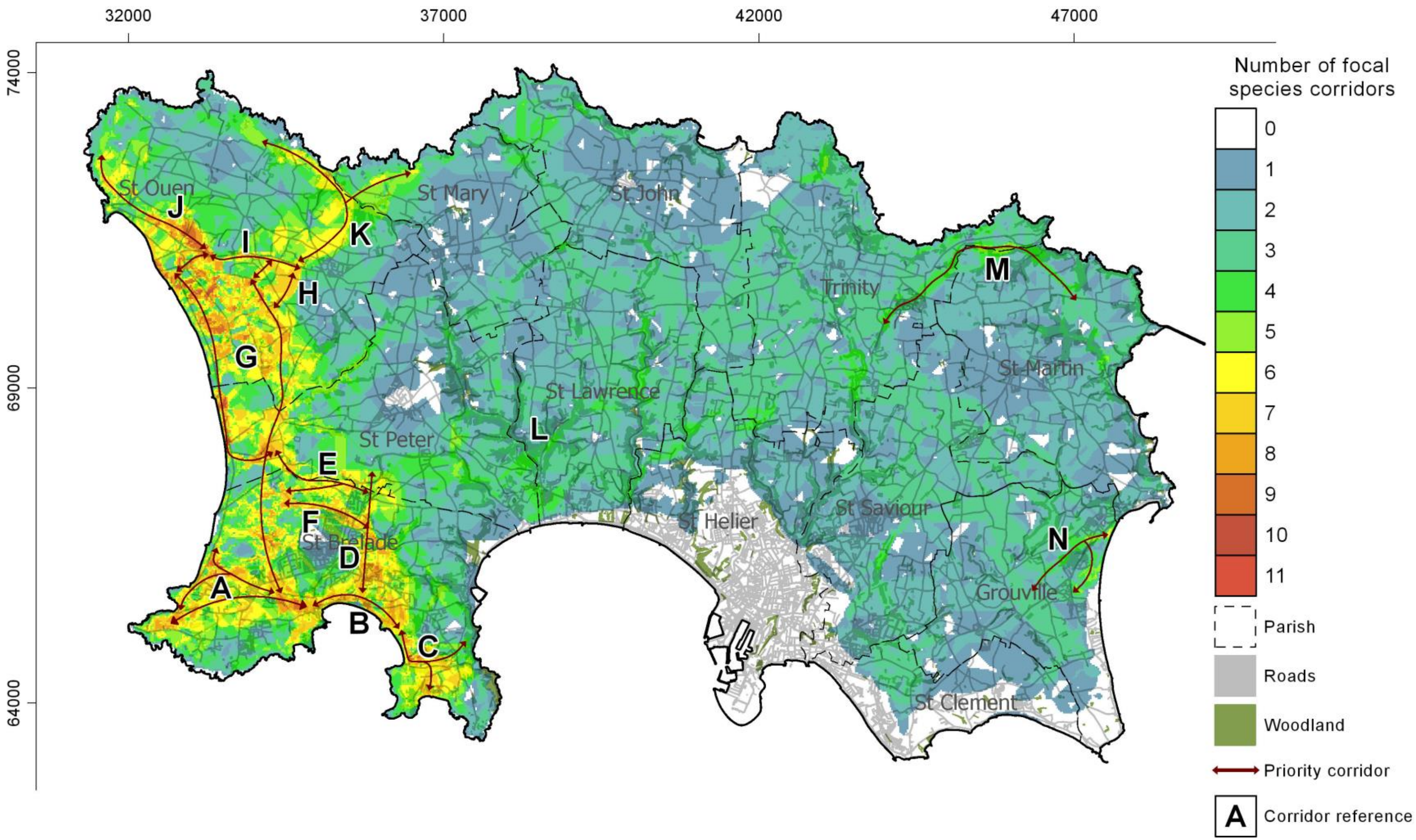


Figure 13 Summary map of priority areas containing high corridor overlap. This is based on the corridors of 12 non-urban focal species with a dispersal limit of 1000 metres. Warmer colours indicate greater corridor overlap across species. Areas of high corridor overlap are indicated as priority corridors with red arrows. Reference letters (A–N) correspond to routes described in the text. No route is shown for 'L' as this applies generally to woodland corridors. Parish boundaries and roads are shown to assist with wayfinding. Coordinates shown are in Jersey Transverse Mercator.

Step 5 – Areas important for connectivity

The connectivity indices tested varied in the correlation strength with one another (Appendix G), with high correlations (≥ 0.7) for most species between $dIIC_k$ and other indices, and dPC_k and other indices. However, $dPCconnector_k$ had a relatively low correlation with other indices in most cases, suggesting it is appropriate for the assessment of connectivity in a different context to both the Probability of Connectivity and the Integral Index of Connectivity. Though $dIIC_k$ and dPC_k showed strong correlations for many species, their recommended use in the literature and variation for some species meant that we retained both. Therefore, we continue with the use of three indices; $dIIC_k$, dPC_k and $dPCconnector_k$.

Maps showing connectivity scores for each of these three indices for each focal species are shown in Appendix G. After rescaling the outputs, the HCAs with greatest connectivity tended to be in the west of the island and within the central wooded valleys when considering all 17 focal species excluding built-up areas or 12 focal species excluding built-up areas after removing urban-dwelling focal species. The five urban-dwelling focal species with ≥ 10% HCAs in built-up areas showed a different pattern (Figure 16), with connective HCAs occurring within the wooded valleys and several coastal regions. This includes support for an important connective region situated along the south coast escarpment along St Brelade’s bay, which is further highlighted as of value by the $dPCconnector_k$ metric in all three focal species scenarios.

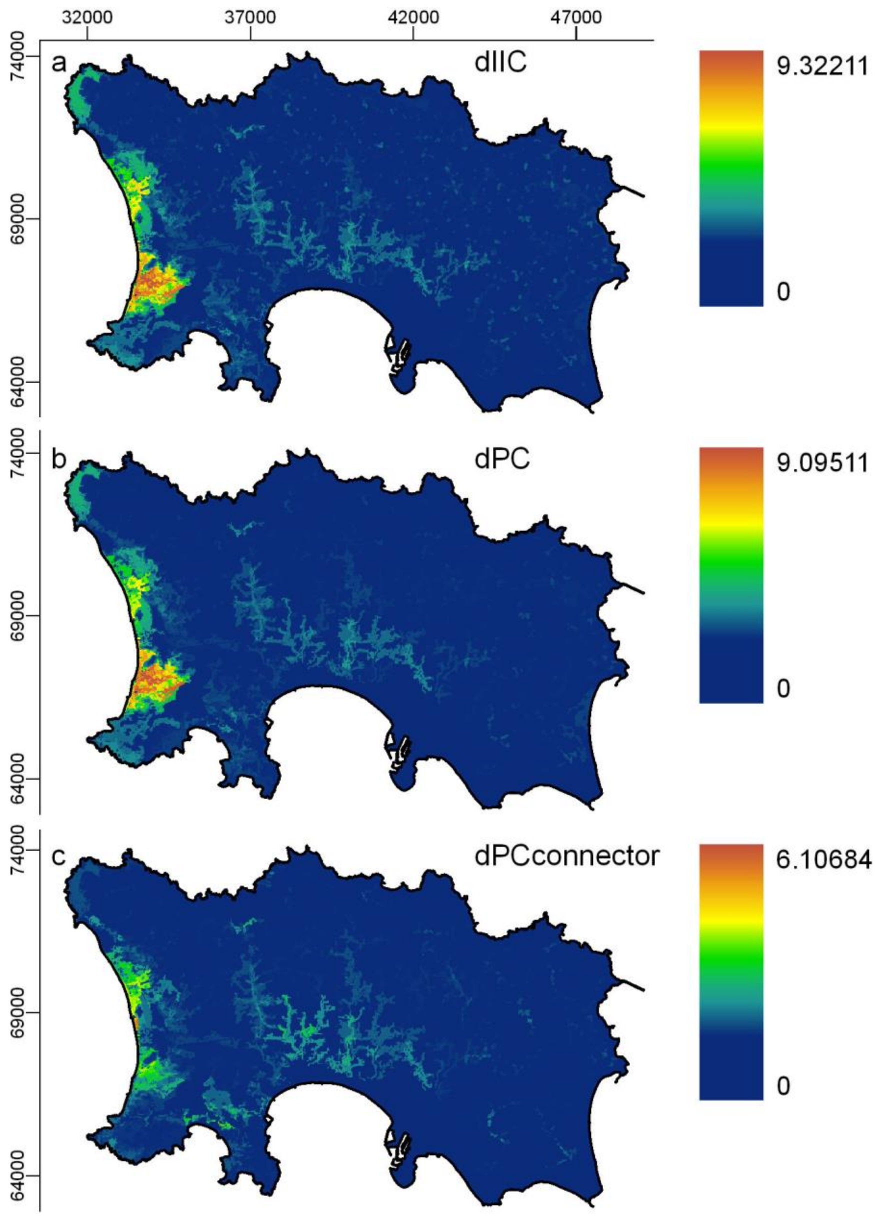


Figure 14 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 17 focal species. Scores are shown as the sum of standardised scores across the 17 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

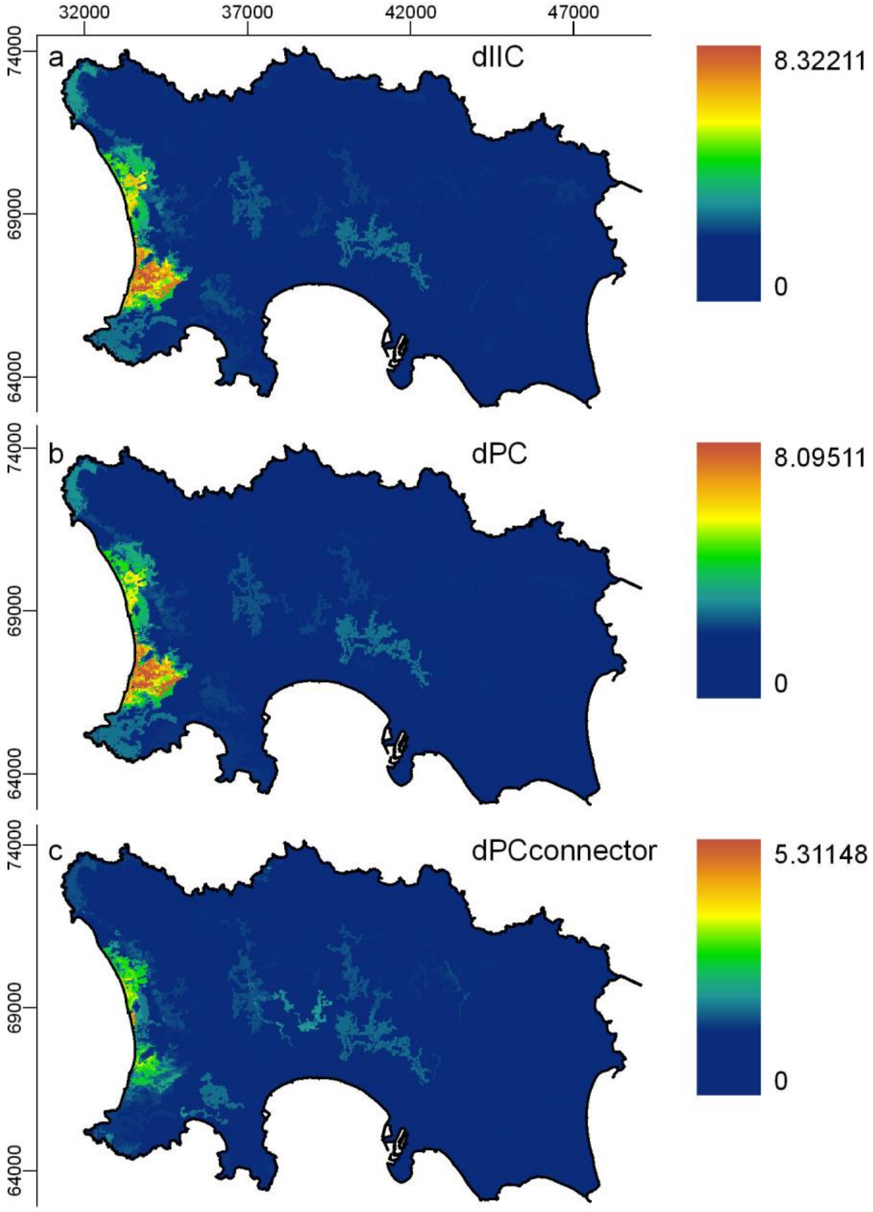


Figure 15 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species. Scores are shown as the sum of standardised scores across the 12 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

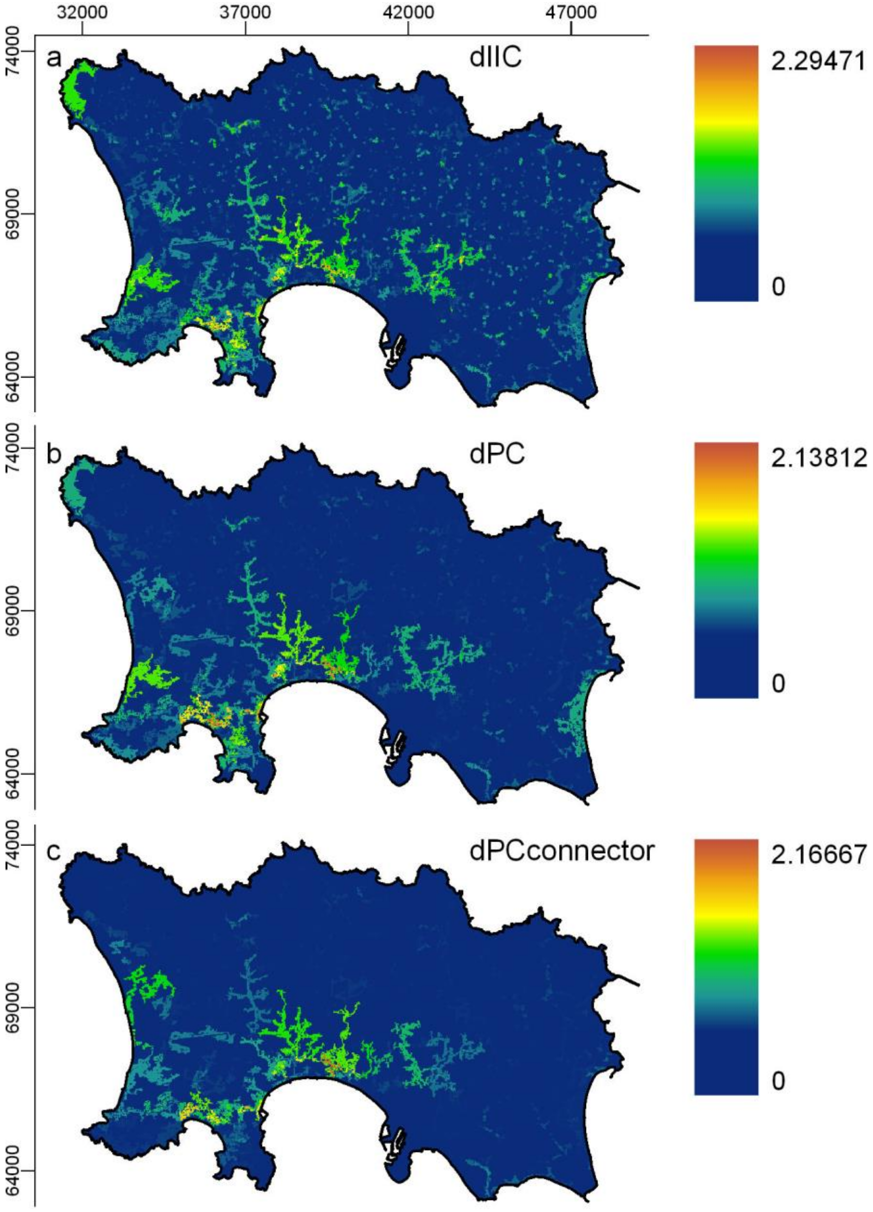


Figure 16 Connectivity scores for Habitat Concentration Areas (HCAs) including built-up areas for five urban-dwelling focal species. Scores are shown as the sum of standardised scores across the five urban-dwelling focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

Opportunities for conservation

Cross-referencing the HCAs of high connectivity with our various designations revealed multiple priority areas of varying levels of protection. Specific priorities were generally similar between *dIIC* and *dPC* indices (Figures 14–16). In comparison, the *dPCconnector* fraction tended to put less emphasis on large patches, due its focus on measuring the importance of a patch in providing connectivity between other patches (e.g. as stepping-stones).

A summary of the priority areas is given in Table 12, highlighting the variation in connectivity indices for prioritisation and the overlap between areas of high connectivity and various designations relevant to wildlife conservation. The table also lists known landowners or managers within those priority areas. We first give priority to areas outside of existing statutory designations due to the risk they face of being lost or managed inappropriately for wildlife.

Outside of SSI and JNP designations (Figures 17–19): priority HCAs were largely centred around the island's wooded valleys (CAs D1–D5: Enclosed Valleys). In particular, high connectivity was seen in the enclosed woodland valleys and surrounding areas along the railway walk from St Aubin to Pont Marquet (CA D3), St Peter's valley and Waterworks valley (CA D1), and the southern ends of Bellozanne Valley and La Vallée des Vaux (CA D2). The escarpment behind St Brelade's bay (CA C2: South Coast Escarpment) was also of high priority but only for the urban-dwelling species. Several semi-urban areas or those adjacent to roads were also of high importance for connectivity, particularly for the urban-dwellers. Many of these areas have been identified by previous work to evaluate Environmentally Sensitive Areas (ESAs) (Penny Anderson Associates 2010).

Within the JNP but outside of SSIs (Figures 20–22): Les Mielles and other areas north of St Ouen's pond (CA B5: St Ouen's Bay Coastal Plain) held strong value for connectivity. Land to the west and north of Le Val de La Mare Reservoir was also of high value (CA C3: St Ouen's Bay Escarpment and Valleys), however the reservoir itself only showed importance for urban-dwellers; namely toads. An area to the north of St Mary's village also showed high priority across the board, and may provide a valuable linkage between urban areas and the north coast. Several other high connectivity areas within the JNP fell adjacent to roads, but with less support than many other areas. High connectivity for urban-dwellers within the JNP was also seen for Beauport, Grouville and the coastline between St Catherine's and Gorey.

Within SSIs (Figures 23–25): many of the areas of highest connectivity occurred within SSIs, with Les Blanches Banques being of particular value. Other areas that fell partially, or completely within existing SSIs were St Ouen's pond and the area north of it within Les

Mielles (CA B5: St Ouen's Bay Coastal Plain), between Les Quennevais and La Corbière along the railway walk and nearby headlands, Les Landes de l'Est and La Lande du L'Ouest. Ouaisné, Portelet and Noirmont showed lower overall connectivity values unless assessing the five urban-dwelling focal species.

Ownership of these areas included the States of Jersey, multiple golf courses, the National Trust for Jersey and Simon Sand. Jersey Water also owned high connectivity areas outside of the SSIs.

Overall priorities for protection: connectivity scores across all scenarios are shown against landscape designations in Figures 26–28. However, we base our overall priorities on the 12 non-urban focal species and the Integral Index of Connectivity (*dIIC*) metric (Figure 29), and recommend the following areas be prioritised for protection:

- north-western portion of St Peter's Valley woodland (Figure 30f; CA D1: Main Interior Valleys)
- southern portion of
    - Waterworks Valley,
    - Bellozanne Valley and
    - La Vallée des Vaux (Figure 30g; CAs D1 & D2: Main Interior Valleys & Eastern Plateau Valleys)
- the enclosed wooded valley from St Aubin to Pont Marquet (along the railway walk) (Figure 30g; CA D3: St Brelade Valley)
- Les Mielles Nature Reserve (Figure 30b; CA B5: St Ouen's Bay Coastal Plain)
- St Ouen's Bay escarpment (Figure 30b; CA C3: St Ouen's Bay Escarpment and Valleys)
- The coastal plains between Les Blanches Banques and La Mare au Seigneur, including Simon Sand (Figure 30c) and Les Mielles Golf and Country Club (Figure 30d; CA B5: St Ouen's Bay Coastal Plain)
- The escarpment from Les Pres D'Auvergne northwest to Les Landes de l'Est (Figure 30a; CAs A1 & C3: North Coast Heathland & St Ouen's Bay Escarpment and Valleys)
- Railway walk and surrounding areas, from La Corbière to Les Quennevais (Figure 30e; CA A2: South West Heathland)
- Extension of Les Blanches Banques SSI on to La Moye Golf Course (Figure 30d)

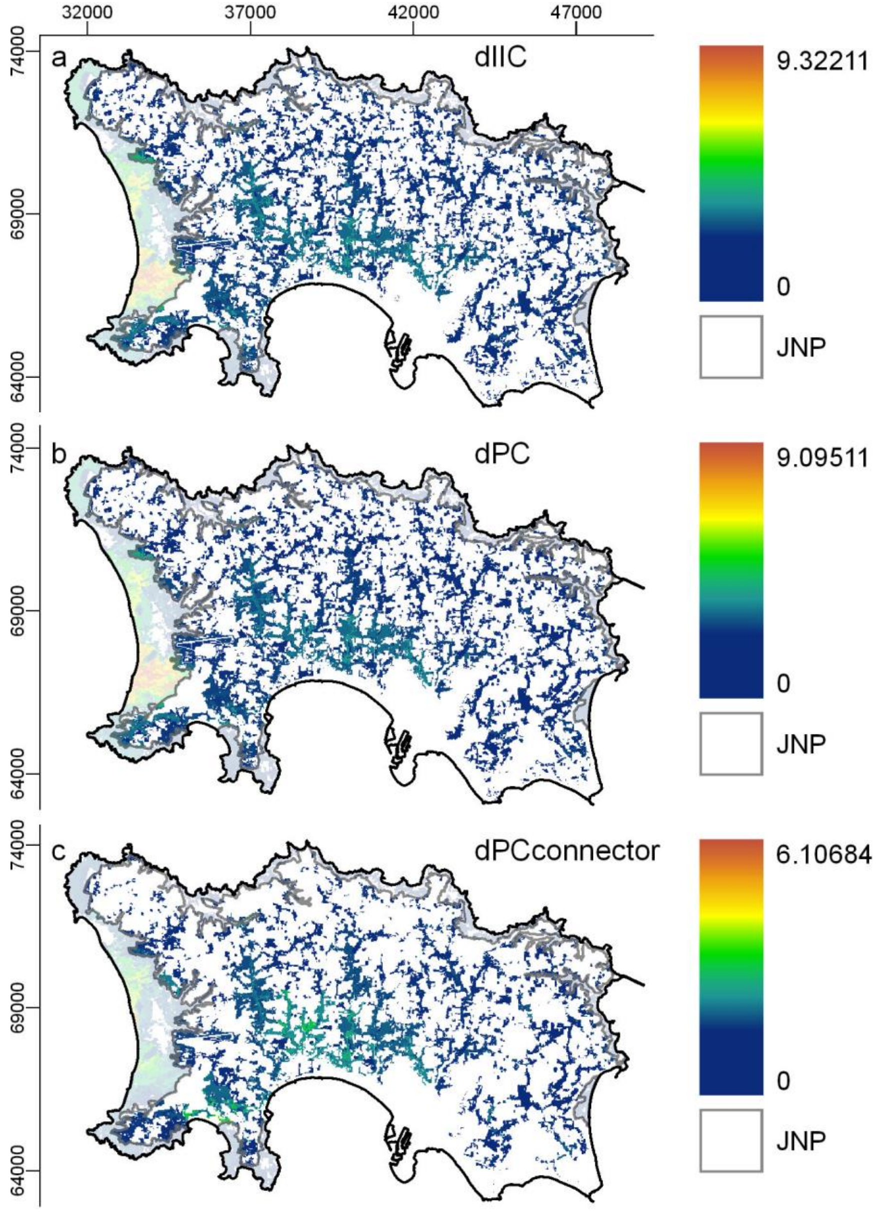


Figure 17 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 17 focal species and with areas of the Jersey National Park (JNP) masked out. Scores are shown as the sum of standardised scores across the 17 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

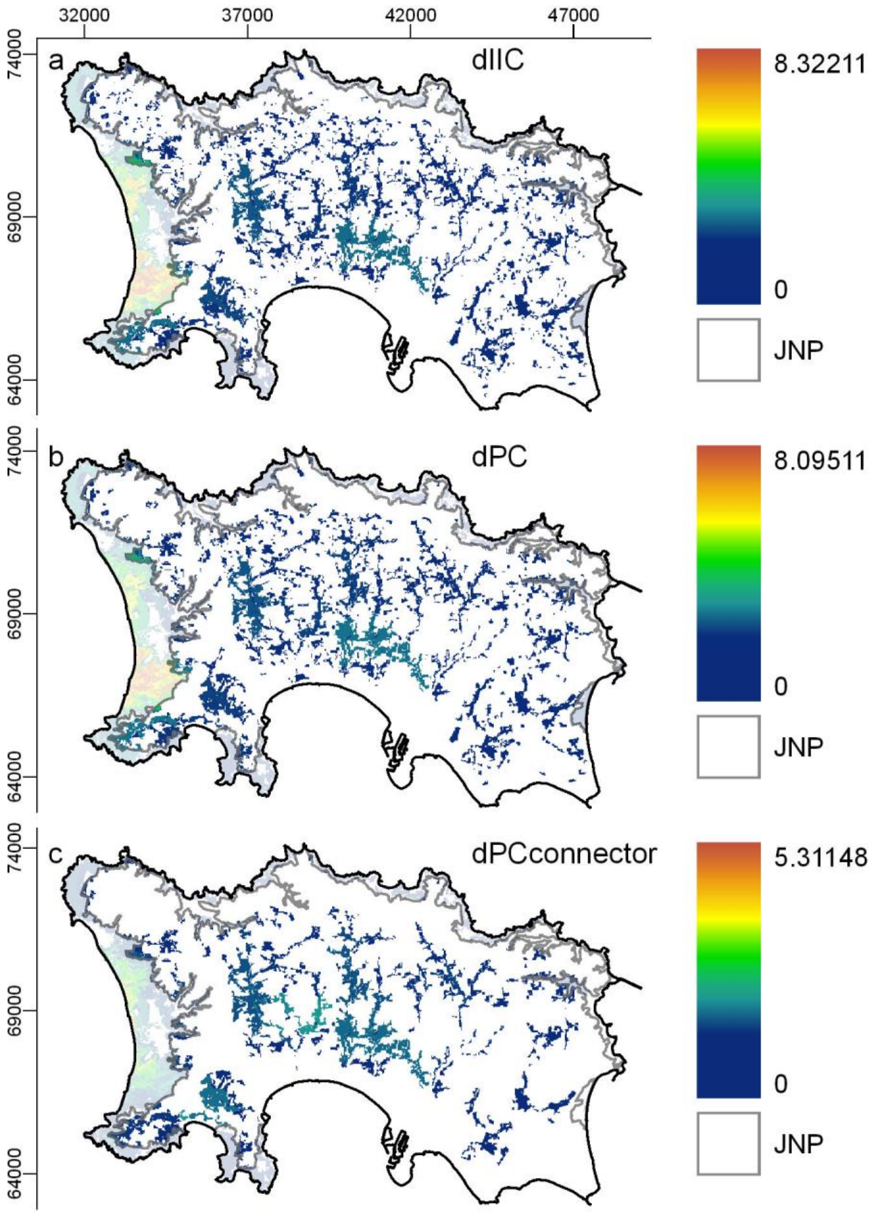


Figure 18 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species and with areas of the Jersey National Park (JNP) masked out. Scores are shown as the sum of standardised scores across the 12 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

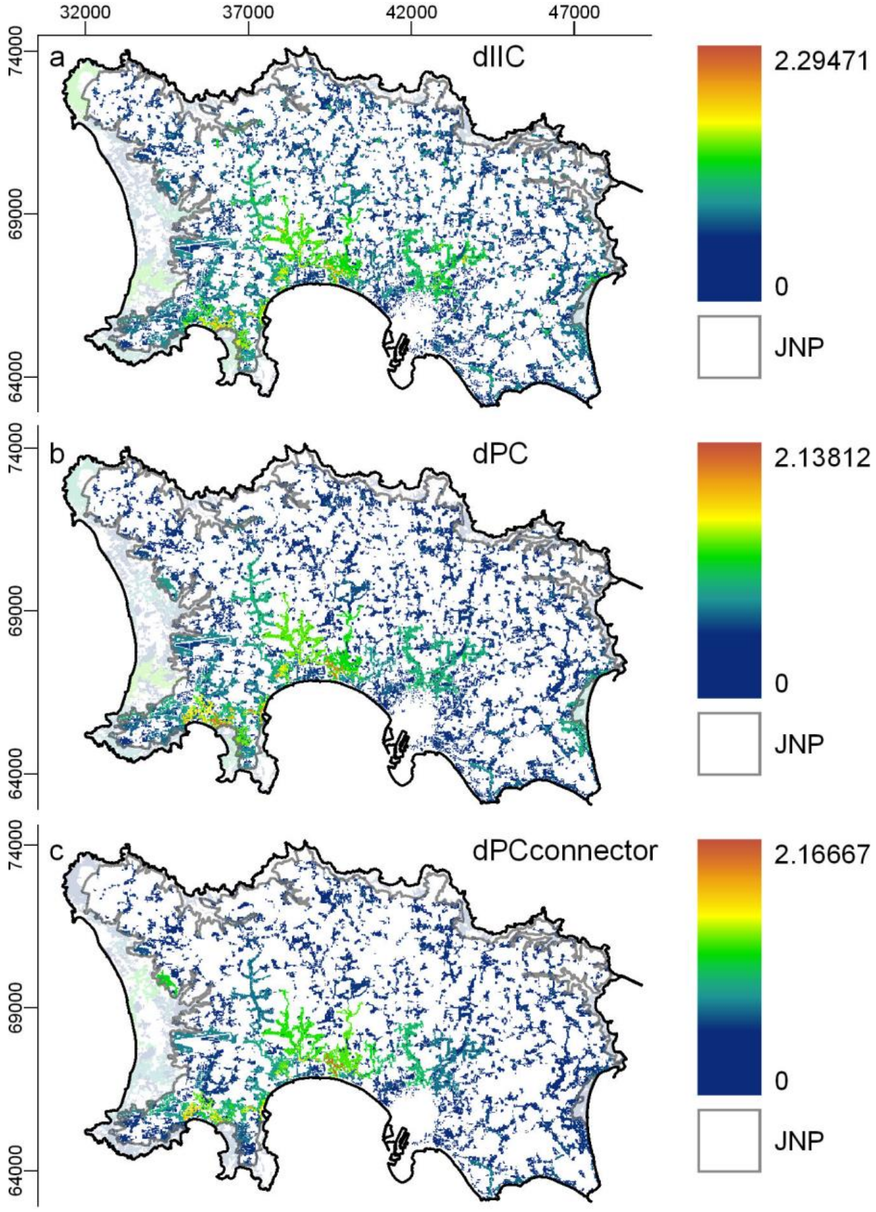


Figure 19 Connectivity scores for Habitat Concentration Areas (HCAs) including built-up areas for five urban-dwelling focal species and with areas of the Jersey National Park (JNP) masked out. Scores are shown as the sum of standardised scores across the five urban-dwelling focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

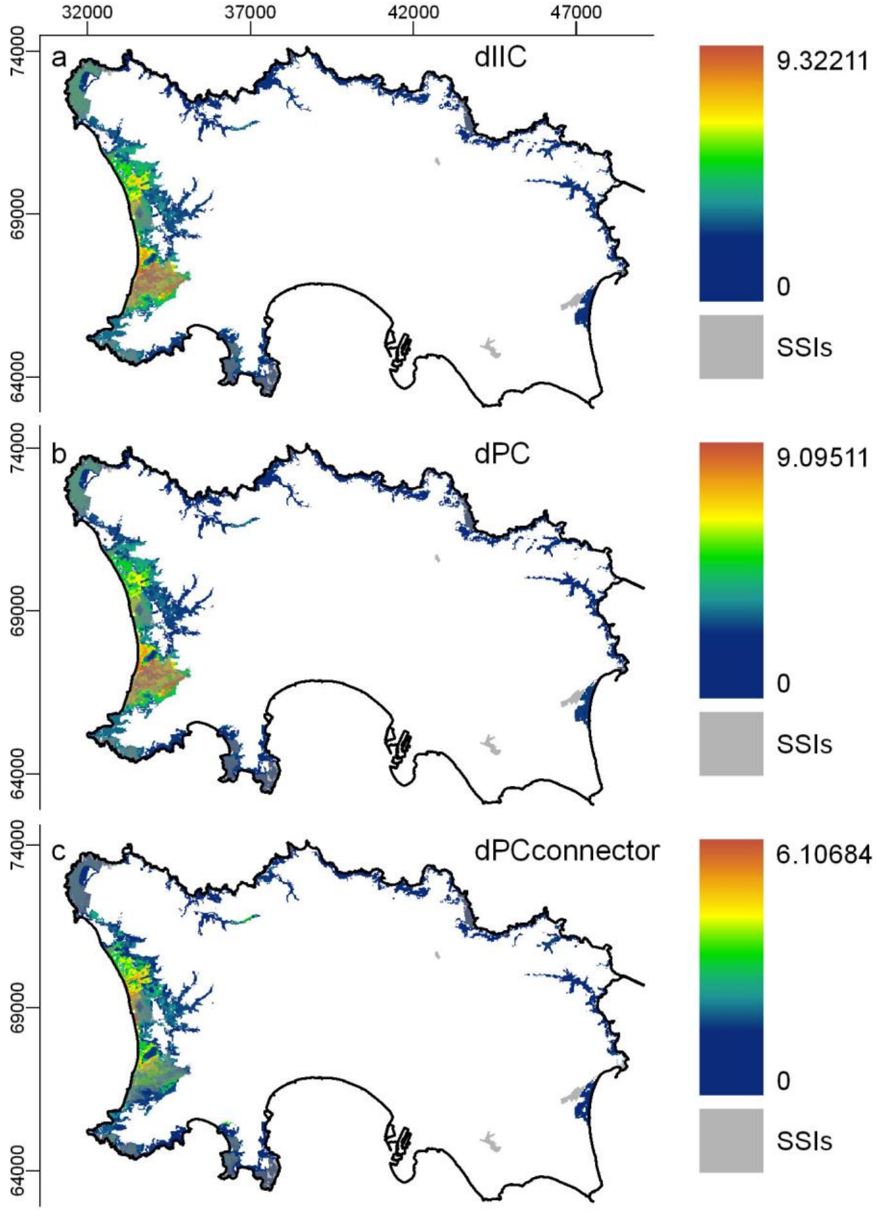


Figure 20 Connectivity scores for Habitat Concentration Areas (HCAs) in the Jersey National Park (JNP) excluding built-up areas for 17 focal species and with Sites of Special Interest (SSIs) masked out in grey. Scores are shown as the sum of standardised scores across the 17 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

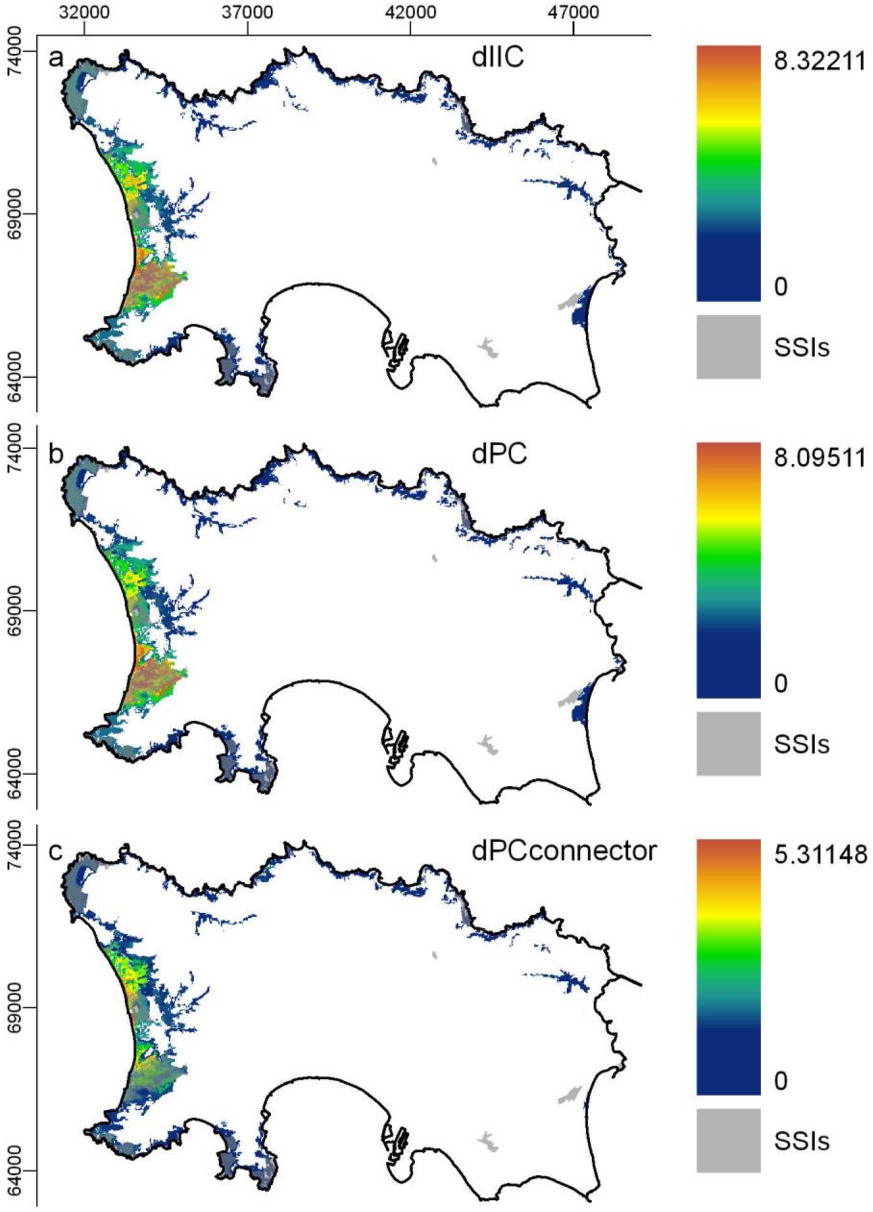


Figure 21 Connectivity scores for Habitat Concentration Areas (HCAs) in the Jersey National Park (JNP) excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species and with Sites of Special Interest (SSIs) masked out in grey. Scores are shown as the sum of standardised scores across the 12 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

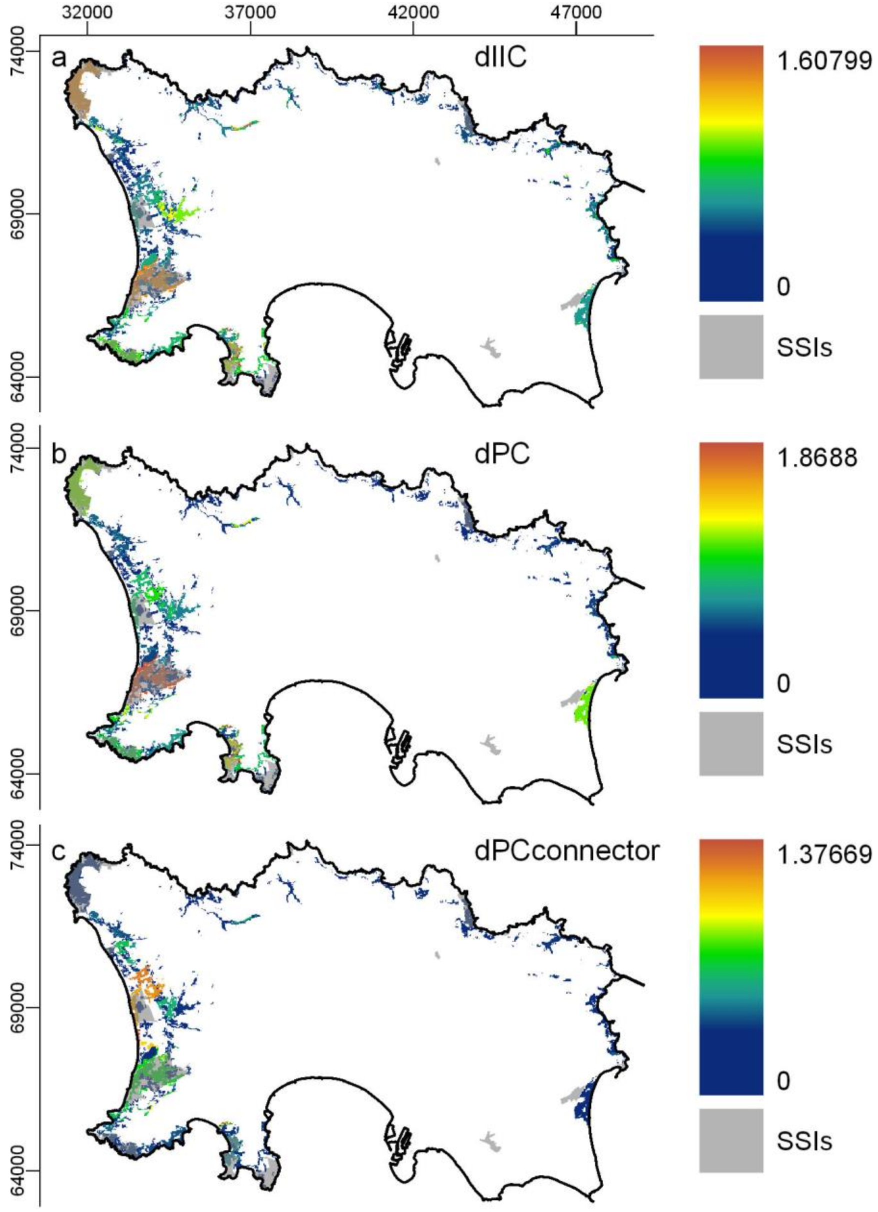


Figure 22 Connectivity scores for Habitat Concentration Areas (HCAs) in the Jersey National Park (JNP) including built-up areas for five urban-dwelling focal species and with Sites of Special Interest (SSIs) masked out in grey. Scores are shown as the sum of standardised scores across the five urban-dwelling focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

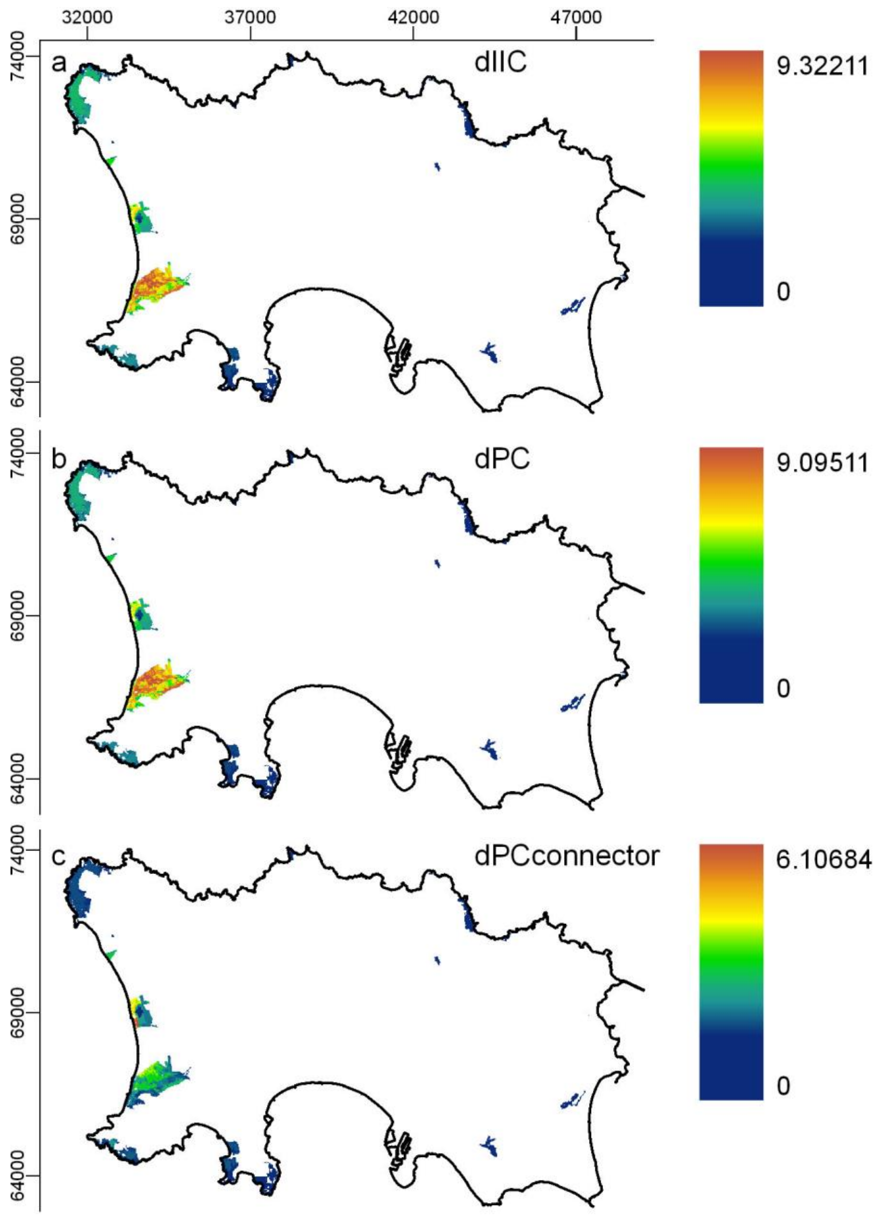


Figure 23 Connectivity scores for Habitat Concentration Areas (HCAs) occurring within Sites of Special Interest (SSIs) excluding built-up areas for 17 focal species. Scores are shown as the sum of standardised scores across the 17 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

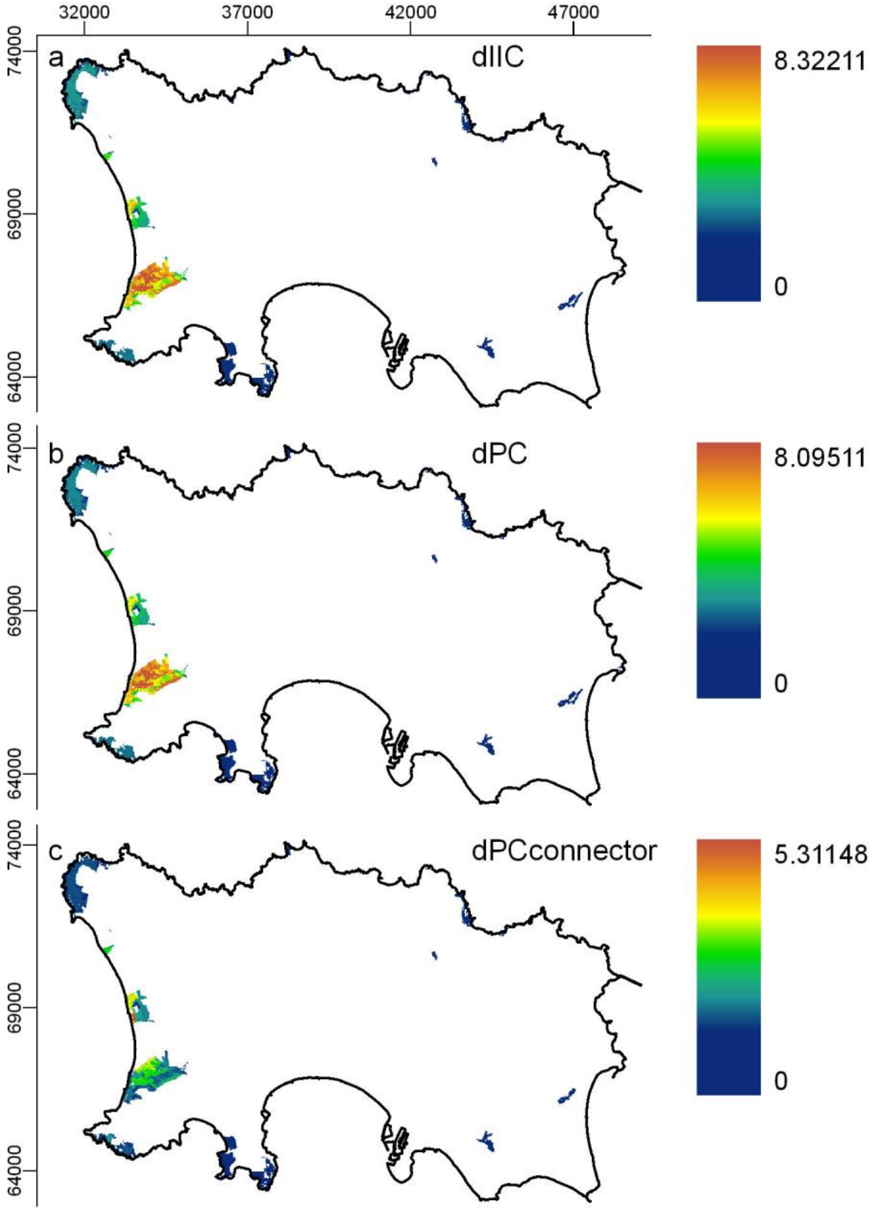


Figure 24 Connectivity scores for Habitat Concentration Areas (HCAs) occurring within Sites of Special Interest (SSIs) excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species. Scores are shown as the sum of standardised scores across the 12 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

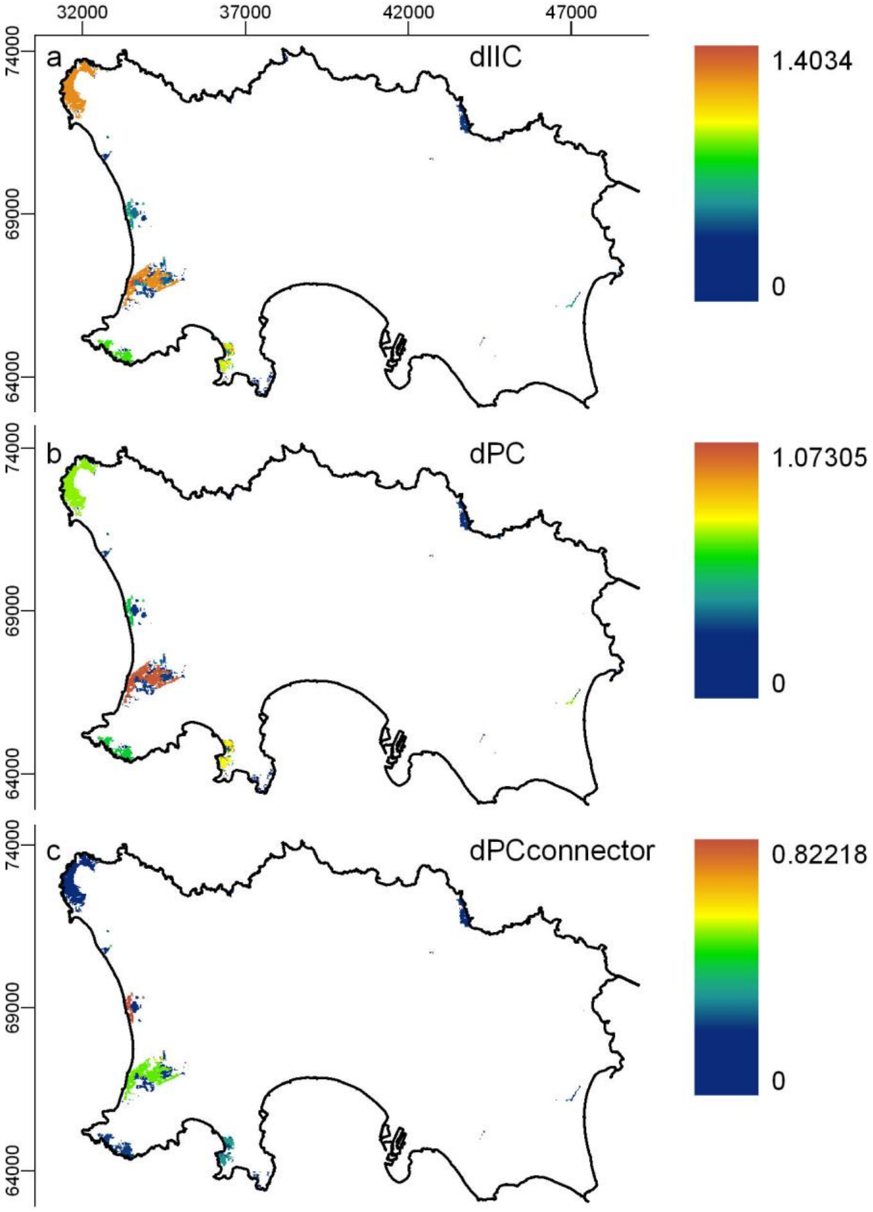


Figure 25 Connectivity scores for Habitat Concentration Areas (HCAs) occurring within Sites of Special Interest (SSIs) including built-up areas for five urban-dwelling focal species. Scores are shown as the sum of standardised scores across the five urban-dwelling focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Coordinates shown are in Jersey Transverse Mercator.

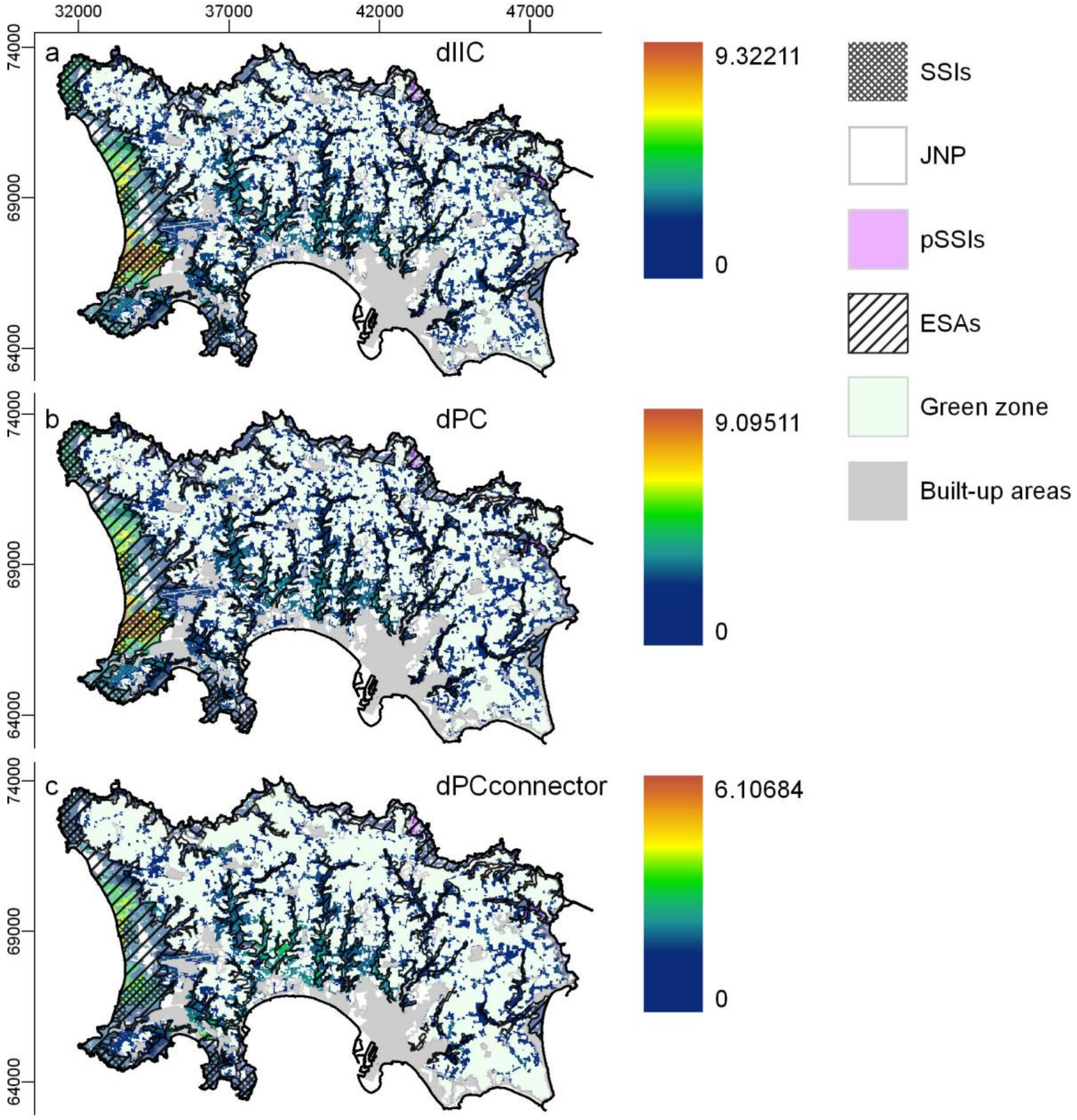


Figure 26 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 17 focal species, overlaid with environmental and planning designations. Scores are shown as the sum of standardised scores across the 17 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Designations were Sites of Special Interest (SSIs), the Jersey National Park (JNP), proposed SSIs (pSSIs) and Environmentally Sensitive Areas (ESAs). Coordinates shown are in Jersey Transverse Mercator.

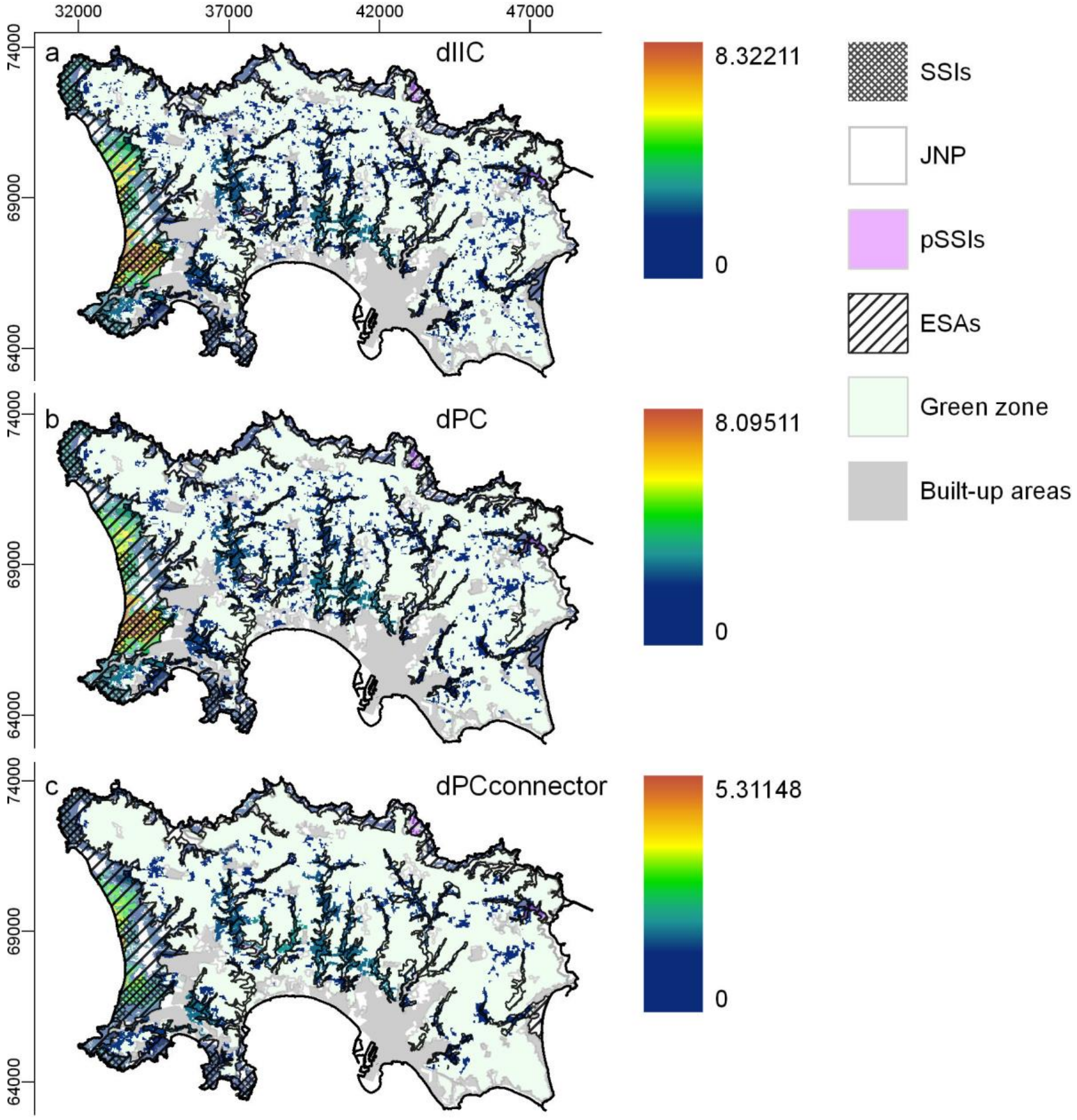


Figure 27 Connectivity scores for Habitat Concentration Areas (HCAs) excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species, overlaid with environmental and planning designations. Scores are shown as the sum of standardised scores across the 12 focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Designations were Sites of Special Interest (SSIs), the Jersey National Park (JNP), proposed SSIs (pSSIs) and Environmentally Sensitive Areas (ESAs). Coordinates shown are in Jersey Transverse Mercator.

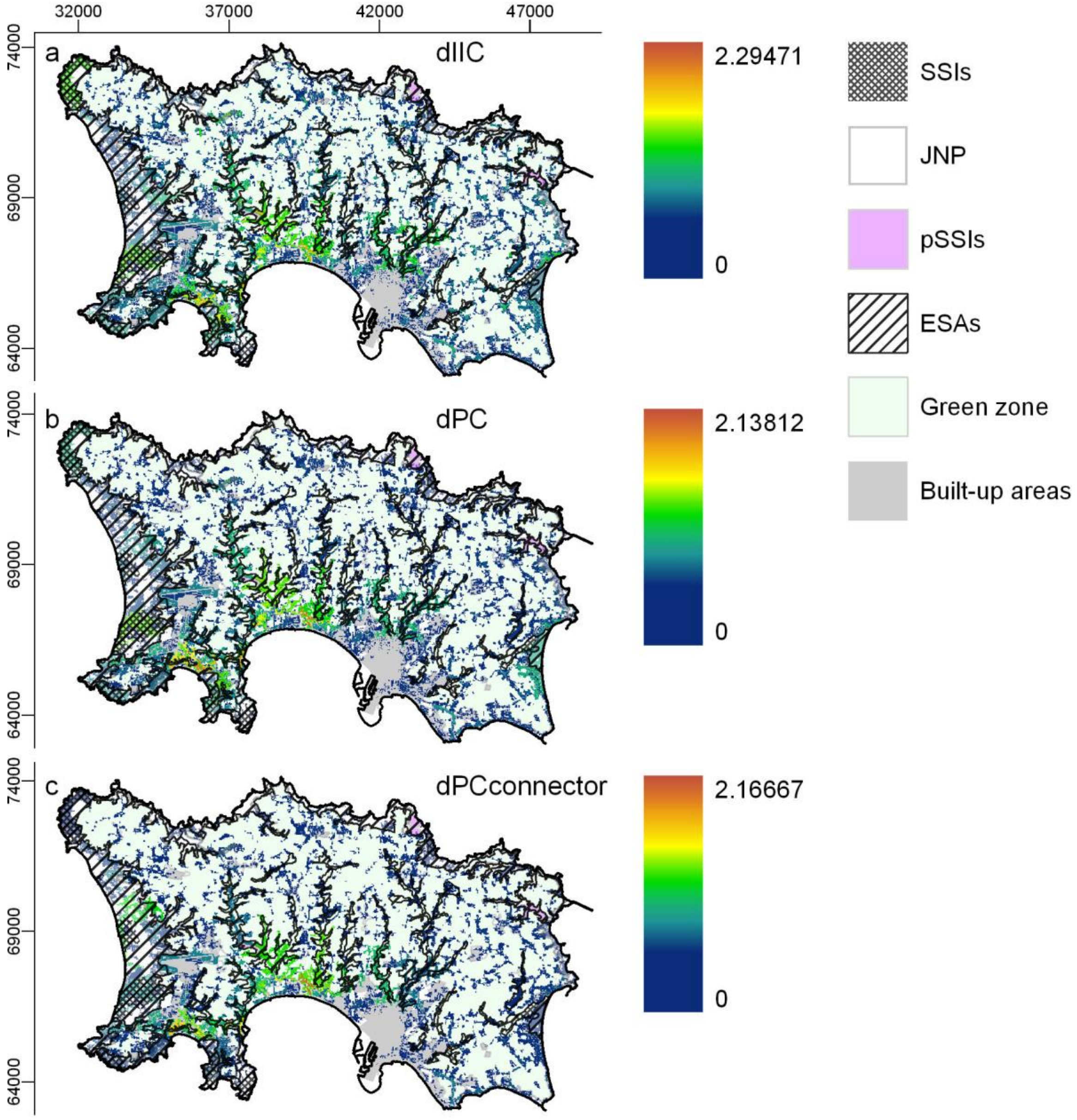


Figure 28 Connectivity scores for Habitat Concentration Areas (HCAs) including built-up areas for five urban-dwelling focal species, overlaid with environmental and planning designations. Scores are shown as the sum of standardised scores across the five urban-dwelling focal species for three indices; (a) the Integral Index of Connectivity (*dIIC*), (b) the Probability of Connectivity (*dPC*) and (c) the connector fraction of the Probability of Connectivity (*dPCconnector*). Warmer colours indicate higher connectivity scores. Designations were Sites of Special Interest (SSIs), the Jersey National Park (JNP), proposed SSIs (pSSIs) and Environmentally Sensitive Areas (ESAs). Coordinates shown are in Jersey Transverse Mercator.

Table 12 Summary of HCAs prioritised for connectivity showing which of three indices (IIC = Integral Index of Connectivity, PC = the Probability of Connectivity, con = the connector fraction of the Probability of Connectivity) they were prioritised by across three separate focal species scenarios (17 focal species excluding built-up areas, 12 focal species excluding urban-dwellers and built-up areas, 5 urban-dwelling focal species including built-up areas). The proportion of a priority area falling within a given designation, statutory or otherwise, is given as 'None', 'Partial' or 'Complete'. Known owners and/or managers of a given area are also listed.

Priority area	Species scenario			Proportion in designation[a]					Ownership and management[b]
	17	12	5	SSI	JNP	pSSI	ESA	LWS	
Enclosed wooded valley from St Aubin to Pont Marquet (along the railway walk) and surrounds including Pont Marquet	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	None	None	Partial	Partial	SoJ / other
Waterworks valley woodland and surrounding land	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	None	None	Partial	Partial	JW / NTJ / other
Southern end of Bellozanne Valley and surrounding land	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	None	None	Partial	Partial	SoJ / NTJ / JW / other
Southern end of La Vallée des Vaux and surrounding land	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	None	None	Partial	Partial	JW / NTJ / other
South and western end of St Peter's valley and surrounding land	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	None	Partial	Partial	Partial	SoJ / NTJ / JW / other
North of Les Creux	IIC/PC/con	IIC/PC	IIC/PC/con	None	None	None	Partial	Partial	SoJ / other
Le Vier Mont and surrounding land / Longueville	IIC/PC/con	–	IIC/PC/con	None	None	None	Partial	None	other
Eastern end of St Aubin's village	IIC/PC/con	–	IIC/PC/con	None	None	None	Partial	None	JW / other
La Route des Cotils	IIC/PC/con	–	IIC/PC/con	None	None	None	None	None	other
Southern end of Les Grands Vaux valley and surrounding land	IIC/PC	–	IIC/PC/con	None	None	None	Partial	Partial	SoJ / NTJ / JW / other
Escarpment behind St Brelade's bay	–	–	IIC/PC/con	None	None	None	Partial	Partial	SoJ / other

Table 12 continued

Priority area	Species scenario			Proportion in designation[a]					Ownership and management[b]
	17	12	5	SSI	JNP	pSSI	ESA	LWS	
Jersey airport	–	–	IIC/PC/con	None	None	None	None	None	SoJ / other
La Grande Route de St Clément	–	–	IIC/PC/con	None	None	None	None	None	SoJ / SC Golf / other
Red Houses	–	–	IIC/PC/con	None	None	None	None	None	SoJ / other
Queen's Valley Reservoir	–	–	IIC	None	None	None	Complete	Partial	JW / SoJ
Les Carrières, St. Martin	con	–	–	None	None	None	None	None	other
St Aubin's village	–	–	IIC/PC/con	None	None	None	None	None	SoJ / other
West of Le Val de La Mare	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	Complete	None	Complete	None	SoJ / NTJ / other
Eastern end of St Brelade's bay including area adjacent to Mont Sohier	IIC/PC/con	con	IIC/PC/con	None	Partial	None	Partial	None	SoJ / other
Area north of St Mary's village	IIC/PC/con	IIC/PC/con	IIC/PC/con	None	Partial	None	Partial	None	other
East of Route de L'Etacq	con	–	con	None	Partial	None	Complete	None	SoJ / other
La Rue de Maupertuis	IIC/PC	–	–	None	Partial	None	Partial	None	other
North of La Mont du Ouaisné	IIC/PC/con	–	IIC/PC/con	Partial	Partial	None	Partial	Partial	SoJ / other
Mourier Valley including headland	–	con	–	None	Complete	None	Complete	Partial	JW / NTJ
Beauport	–	–	IIC/PC	None	Partial	None	Partial	Partial	SoJ / NTJ / other
Grouville	–	–	IIC/PC	None	Partial	None	Partial	None	RJ Golf / SoJ / other
Le Val de La Mare reservoir	–	–	IIC/PC	None	Complete	None	Complete	Partial	JW
St Catherine's to Gorey coastline	–	–	IIC	None	Partial	None	Partial	None	SoJ / other
St Ouen's bay coastal plain and escarpment	IIC/PC/con	IIC/PC/con	IIC/PC/con	Partial	Partial	None	Complete	Partial	SoJ / NTJ / LMi Golf / other

Table 12 continued

Priority area	Species scenario			Proportion in designation[a]					Ownership and management[b]
	17	12	5	SSI	JNP	pSSI	ESA	LWS	
Railway walk and surrounds, west of Quennevais to La Corbière and headlands	IIC/PC/con	IIC/PC/con	IIC/PC/con	Partial	Partial	None	Partial	Partial	SoJ / LMo Golf / other
Les Landes de l'Est	IIC/PC/con	IIC/PC/con	IIC/PC/con	Complete	Complete	None	Complete	None	SoJ / other
Les Blanches Banques and surrounding areas	IIC/PC/con	IIC/PC/con	IIC/PC/con	Partial	Complete	Partial	Complete	None	SoJ / LMo Golf / LO Golf / SS / other
La Lande du L'Ouest	IIC/PC/con	IIC/PC/con	IIC/PC	Partial	Partial	None	Partial	None	SoJ / other
Ouaisné	–	–	IIC/PC/con	Partial	Complete	None	Complete	None	SoJ / other
Portelet	–	–	IIC/PC/con	Partial	Partial	None	Partial	None	JW / NTJ / other
Noirmont	–	–	IIC/PC/con	Partial	Partial	None	Partial	None	SoJ / other

[a] Designations listed: SSI = Sites of Special Interest; JNP = Jersey National Park; pSSI = proposed SSIs; ESA = Environmentally Sensitive Areas; LWS = Local Wildlife Sites (not designated but based on knowledge of site management and use).

[b] Owners and managers: SoJ = States of Jersey; JW = Jersey Water; NTJ = National Trust for Jersey; SC Golf = St Clement's Golf Course; RJ Golf = Royal Jersey Golf Course; LMi Golf = Les Mielles Golf and Country Club; LMo Golf = La Moye Golf Club; SS = Simon Sand.

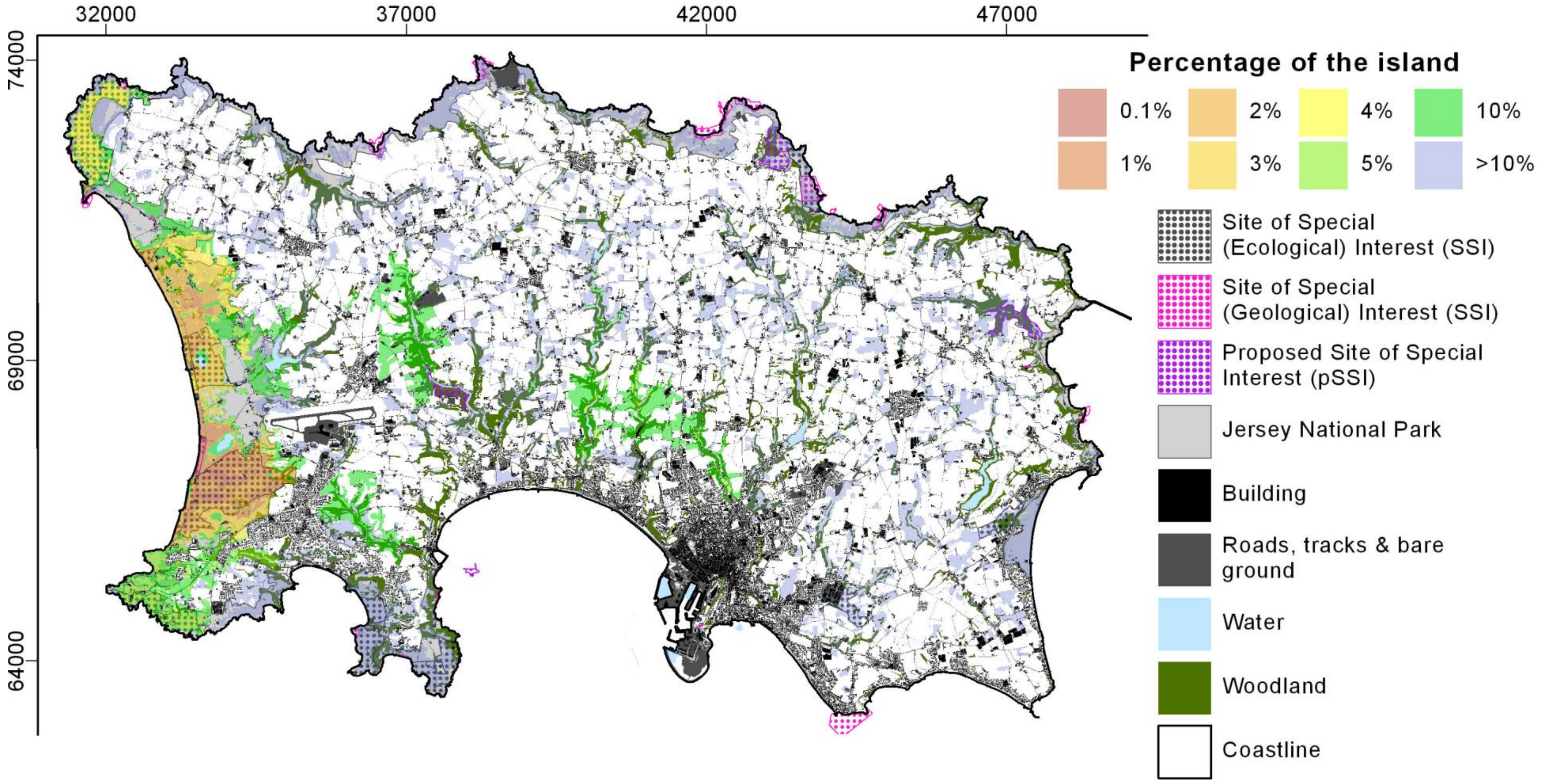


Figure 29 Priority areas for protection based on connectivity scores for Habitat Concentration Areas (HCAs); excluding built-up areas for 12 focal species after the exclusion of five urban-dwelling species. Priority areas are shown from red to green, in order of contribution to connectivity and the proportion of the island that can be protected (i.e. red areas contribute the most to connectivity and constitute 0.1% of the island's surface). Percentages are calculated from the sum of standardised scores across the 12 focal species for the Integral Index of Connectivity (*dIIC*). Landcover designations are shown for reference. Landcover features are shown to assist with wayfinding. Coordinates shown are in Jersey Transverse Mercator. Detailed maps are given in Figure 30.

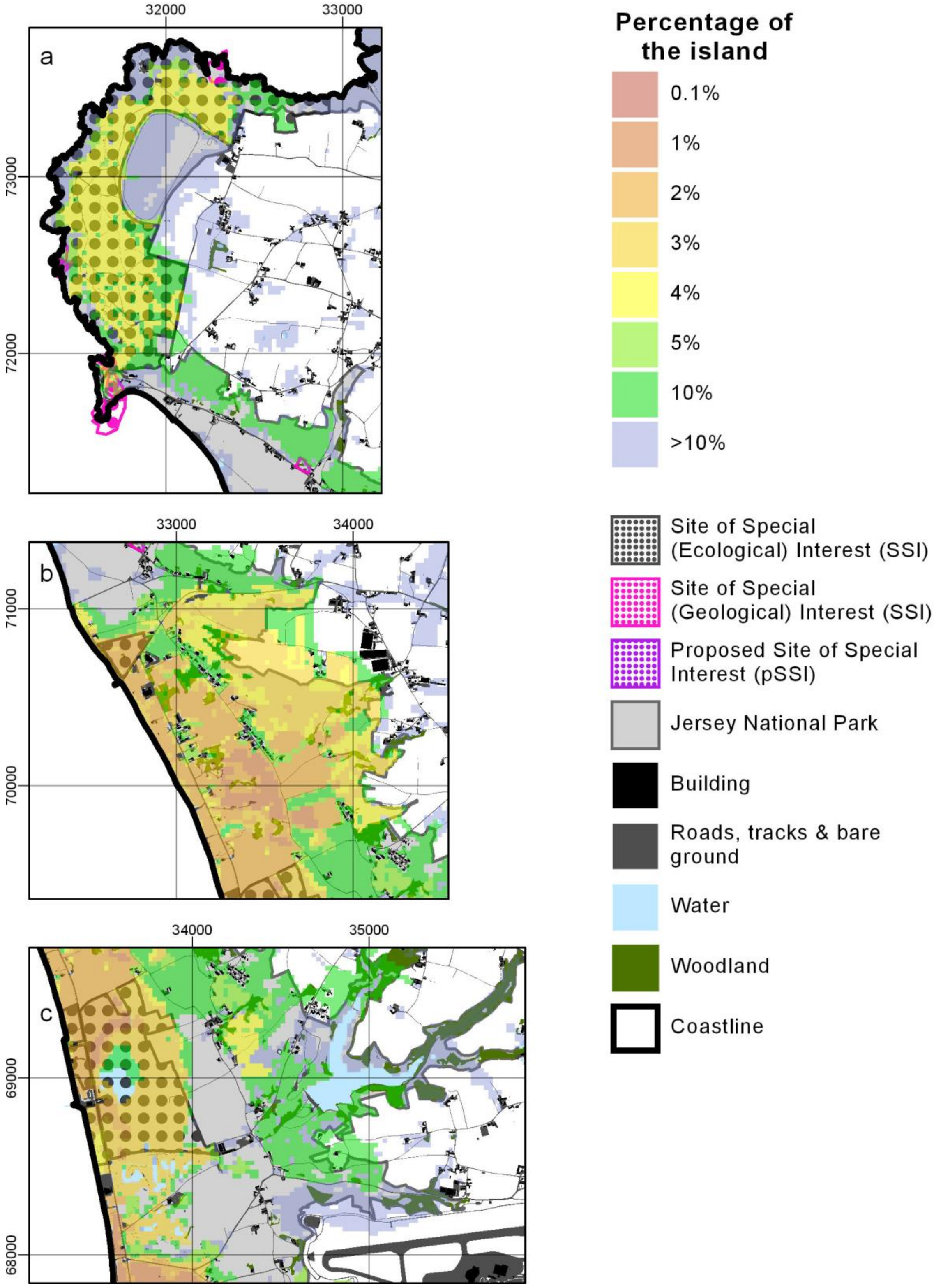
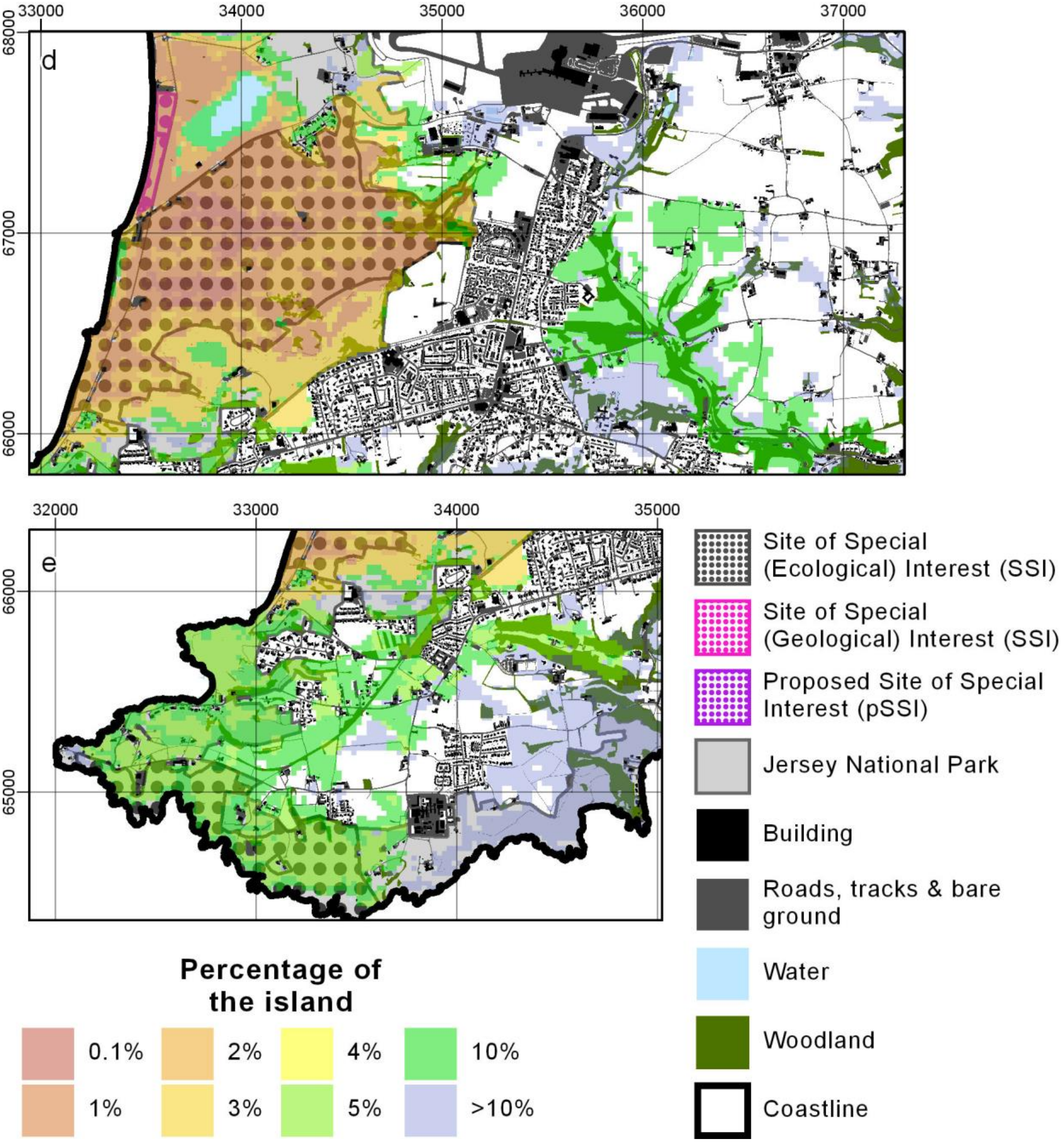


Figure 30 Maps showing areas of high priority for protection (highlighted in colour). These are: a) the northwest coastline including Les Landes de l'Est, b) Les Mielles and escarpment, c) St Ouen's pond and Le Val de La Mare, d) Les Blanches Banques and St Brelade's Valley woodland, e) the southwest coastline and railway walk, f) St Peter's Valley woodland and g) Waterworks Valley, Bellozanne Valley and La Vallée des Vaux. **Maps continue across three pages**. Priority areas are rated by contribution to connectivity (red = high, blue = low) and the cumulative percentage of the island they cover.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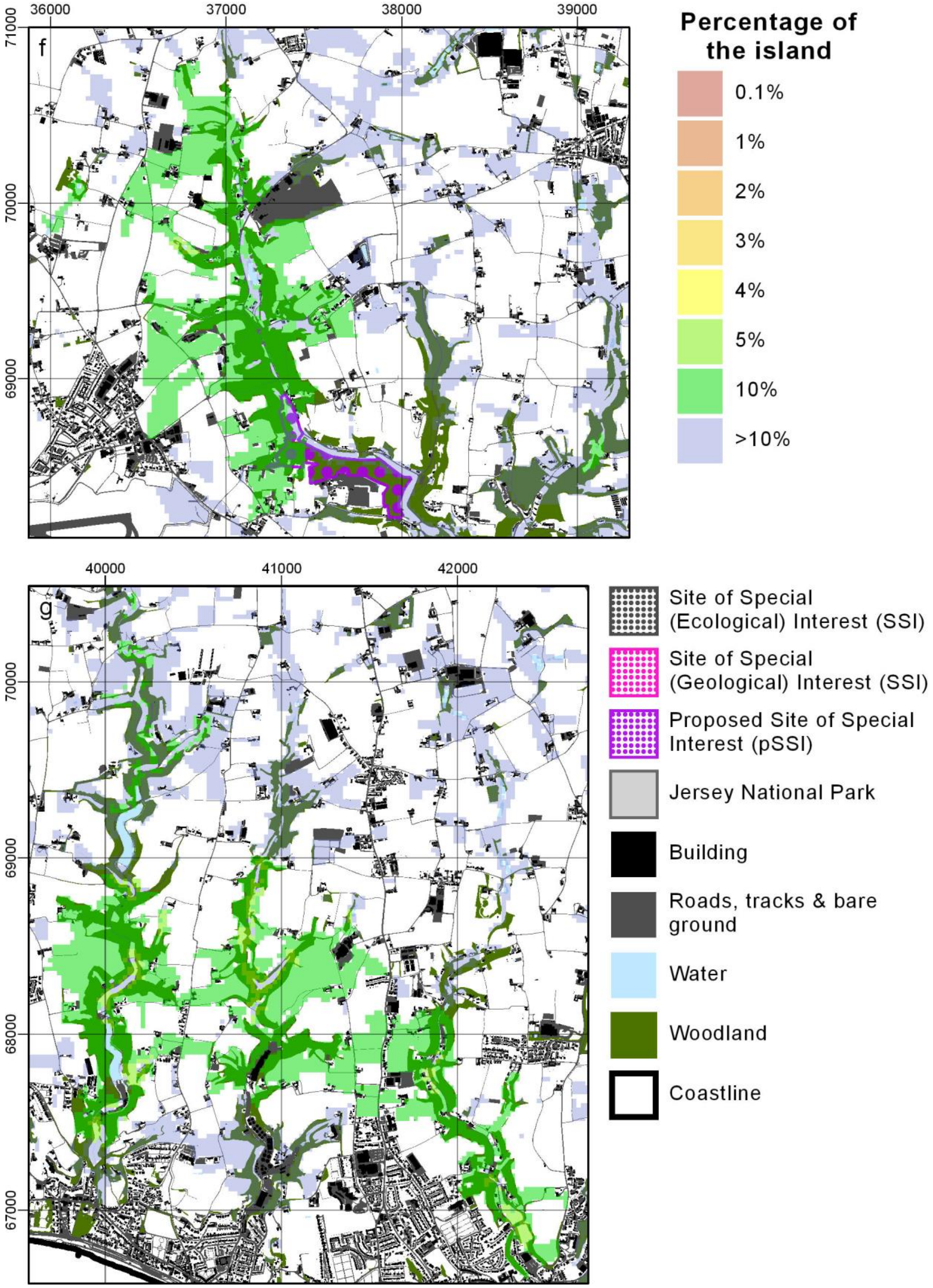
Site of Special (Ecological) Interest (SSI)
Site of Special (Geological) Interest (SSI)
Proposed Site of Special Interest (pSSI)
Jersey National Park
Building
Roads, tracks & bare ground
Water
Woodland
Coastline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>10%
Site of Special (Ecological) Interest (SSI)
Site of Special (Geological) Interest (SSI)
Proposed Site of Special Interest (pSSI)
Jersey National Park
Building
Roads, tracks & bare ground
Water
Woodland
Coastline

Discussion

Within this report we have summarised the existing protections for both habitats and species in Jersey. We have also used species occurrence data from 17 focal species to identify new areas of high suitability for Jersey's wildlife – referred to as Habitat Concentration Areas (HCAs). Furthermore, we have assessed the contribution of existing statutory designations for affording protection to the island's biodiversity, identified corridors through which wildlife are most likely to move, and provided a prioritisation of HCAs for protection and restoration based on their value to wildlife connectivity and current designation. Our results highlight the importance of utilising a multi-species approach to identify spatial conservation priorities, they provide support to existing designations and to previous opportunity mapping work, and identify priorities for protection, management and restoration expected to be suitable for a wide range of Jersey's wildlife. Crucially, we highlight a number of areas of high importance for providing connectivity and habitat to a wide range of species that do not currently receive protection or directed management.

Selection of focal species

The set of focal species selected in this study represent a range of taxonomic groups with species exhibiting varying dispersal abilities and life-histories. We preferentially selected protected species with specialist habitat requirements and restricted distributions. Our selection was heavily limited by available data held by the JBC and local taxonomic specialist groups (e.g. Jersey Bat Group), with particular biases in the selection of plants towards orchids and a lack of invertebrates with sufficient data. Changes to our selection of focal species may have altered our results, however we are confident that the outputs represent priorities that will suit a wide range of species. Improvements for future analyses could be made by ensuring biological recording is well supported within Jersey, is accessible with easy avenues for reporting observations (i.e. via the Jersey Biodiversity Centre website) and is focused on a diverse subset of species. The work of a centralised repository is invaluable in this sense in coordinating records for further work and enabling analyses. Providing support to, and promoting taxonomic diversity in species recording will go some way towards generating datasets with few biases and good representation of what the 'true' distribution of some species may be. Furthermore, it will ensure that there are sufficient records to provide confidence in any analyses that are carried out. Identifying the species on which surveillance can be focused may be best carried out by first considering the current capacity of Jersey's amateur and professional naturalists, and the schemes currently in place. For instance, Toadwatch has been successful in eliciting toad records and requires little effort on the part of the recorder (Wilkinson and Starnes 2016). Furthermore, a range of monitoring efforts requiring varying degrees of involvement and skill report on reptile, amphibian, bird, bat and butterfly trends, as well as plant distribution and abundance. The presence of the JBC allows records from these, and other recording sources (both structured and ad-hoc) to be collated and stored in a standardised way, thereby facilitating future data analysis.

Factors influencing species distributions

Though variable in their drivers of distribution and habitat suitability, landcover type (i.e. habitat) was shown to be an important predictor for all species assessed. However, the specific landcover types selected varied between focal species. The current ecological knowledge for each of our focal species is briefly summarised in Appendix B. The preference of garden ponds by toads matches that of previous work (Wilkinson and Starnes 2016). Grass snake preferences for rough grassland (i.e. dune grassland) in the west of the island mirror a previous study carried out in Jersey (Ward 2017). The bank vole is typically considered to occur in a range of habitats that provide good vegetative cover (Mcgowan and Gurnell 2014). Our findings were similar, suggesting high importance for several habitat types including various forms of grassland and scrub. Predicted distributions of roosts for both long-eared and common pipistrelle bats were most heavily influenced by the presence of historic buildings, especially for long-eared bats. Though these results may be biased due to most bat emergence surveys being undertaken at properties as part of planning considerations, these results highlight the importance of ensuring adherence to strict planning and building laws for their conservation.

The widespread distribution of the red squirrel was most greatly influenced by their proximity to all forms of woodland, matching previous studies both in and outside of Jersey that woodland is a key habitat for this species (Andrén and Delin 1994; Gurnell et al. 2002; Magris and Gurnell 2002). The apparent preference of the field cricket for areas close to coastal heathland and within dune grassland habitats reflect its coastal distribution, and supports suggestions that areas of open, warm sandy habitat are important. Further detailed analysis incorporating factors such as grass sward height and grazing of areas may produce a more detailed picture of suitability for this species. Waxcap fungi were expected to be associated to the distribution of nutrient-poor grasslands (Schweers 1949). As expected, our results identified them to be most heavily associated to dune and semi-improved grasslands. Similarly, the scaly stalkball showed strong associations to dune marram habitats, owing to its preference for warm sandy habitats (Karadelev and Rusevska 2006; Kaya 2015; Kholfy et al. 2017).

Proximity to varying forms of grassland were most important for the green-winged, pyramidal, lizard and early-purple orchids. The presence of short, often sandy undisturbed grassland is therefore of high importance for these species. In contrast, the southern-marsh orchid was shown to be heavily influenced by the distribution of wetlands, and therefore relies on their appropriate management to provide habitat. The Jersey buttercup preferred coastal areas close to all types of scrub, but limited records mean that predictions should be interpreted with caution. Ragged robin showed clear associations to its preferred wet habitats, whereas autumn lady's-tresses was the only focal species with a clear association to cemeteries; highlighting their conservation value if correctly managed for wildlife. Continuing improvements to our understanding of the habitat preferences and needs of Jersey's wildlife is vital to ensure habitats are managed appropriately.

Habitat Concentration Areas

We observed some overlap between species HCA predictions; particularly those of similar type due to preferences for similar habitats. For example, both common pipistrelle bats and long-eared bats showed an affinity for buildings as roosts. The more prescriptive distribution of long-eared bats for historic buildings meant that much of their predicted distribution fell within that of the common pipistrelle. Similarly, a number of species, particularly orchids, were predominantly known from sites in the west and southwest of the island and as a result had similar HCA predictions. These similarities could lead to resulting conservation priorities being biased towards these same areas. Furthermore, they may also be the result of biases in sampling towards known biodiversity hotspots. However, the overall wide selection of species gives good coverage of the island's important habitats, and in addition we provide individual outputs for each focal species to ensure transparency behind our findings.

The high overlap of HCAs occurring within the west and southwest of the island shows how important these areas are for Jersey's wildlife, and was further validated by other approaches. Many of these areas already benefit from SSI designations, however those that remain unprotected (e.g. Les Mielles Nature Reserve) are high priorities for improved protection. Balancing these protections against the needs of public access and recreational use of sites further supports the approach of including stakeholders in access consultations such as in the recent Countryside Access Strategy report.

Built-up areas

Though natural and semi-natural habitats are generally expected to be of greater importance than human-modified environments such as arable and urban areas, a number of species have adapted to make the most of these alternative environments. Therefore, their sensitivities to land-change are reduced. Examples include use of urban green (e.g. cemeteries, parks) and blue (e.g. reservoirs, garden ponds) spaces. Of the species modelled here, five were considered to utilise urban environments and have been recorded doing so previously (Magris and Gurnell 2002; Wilkinson and Starnes 2016; Jokimäki et al. 2017). The effects of human land-use change are softened upon these species by the provision of supplemental food (e.g. bird and squirrel feeders) (Magris 1998) and garden ponds (for amphibians among other species) (Wilkinson and Starnes 2016). However, living within these areas also increases mortality risk due to the presence of domestic and feral cats or via road collisions (Magris 1998; Magris and Gurnell 2002). This sort of artificial 'improvement' to the landscape can result in greater population densities than would naturally occur, as well as use of habitat patches that otherwise would be unable to support individuals (e.g. Magris and Gurnell 2002). Therefore, they may not be sustainable in the long-term.

Connectivity

How well connected the landscape is, is heavily influenced by the size and distribution of HCAs, and the dispersal ability of the organism of interest. Where HCAs are distant from one another, attempts to provide connectivity are extremely challenging. However, the provision of 'stepping-stone' habitats can help alleviate these issues, and can be a more cost-effective approach than trying to generate continuous corridors of habitat. Our analysis identified the most beneficial areas to develop corridors to be within the island's wooded valleys, and linking various parts of the west and south-west of the island. Similarly, the HCAs of highest priority for connectivity also tended to be in the west of the island and within the wooded valleys. Engaging the various landowners and managers in these areas in the protection, maintenance and restoration of these areas is therefore the most beneficial approach for Jersey's wildlife.

Landscape designations

The current SSIs and the Jersey National Park are of high value for biodiversity, but do not provide sufficient coverage to protect the majority of the HCAs and corridors identified in this study. Areas previously identified as Environmentally Sensitive Areas (Penny Anderson Associates 2010) had strong overlap with our HCAs, providing further support for our findings. We propose that a wider SSI network is developed, with the findings of this report providing justification for several areas. Alternatively, where appropriate, new designations may be developed (e.g. Local Wildlife Sites / Sites of Importance for Nature Conservation and Areas of Special Protection) that will ensure the appropriate protection and management of sites not currently residing within the protected network. Areas selected as SSIs and for other protected site designations for wildlife are often done so simply because those are the semi-natural areas that remain. The findings of this study will contribute to the decision-making process when identifying future priorities for protection, and ensure that the resulting network has improved connectivity. This inclusion of connectivity is important to ensure that protected areas don't simply become isolated islands rich in biodiversity.

Land management

Sites currently valued for wildlife are often managed based on the outcomes of site condition assessments, and in favour of the ecological interest (e.g. species) they have been designated for. Assuming management ensures these sites are of favourable condition, further steps can be taken to improve the overall ecological network. These vary in cost and applicability dependent on the structure of the landscape. Generally, they can be broken down in to four categories; (i) increasing the diversity and quality of habitats where habitat is already in good condition, (ii) increasing the diversity and connectivity of habitats where habitats are more isolated and uniform, (iii) increasing the overall coverage of habitat as well as its connectedness to other habitat blocks and (iv) creating new areas of habitat, either on their own or as extensions of existing habitats (Lawton et al. 2010). Of these strategies, maintaining and improving existing habitat is of lower cost than complete restoration or habitat creation approaches.

Both financial and logistical support is required to secure these enhancements to any ecological network. It is unfeasible to expect all such work to be carried out by local government, nor for all priority areas to be purchased by the government or environmental organisations. Instead, engaging and promoting local landowners and managers to contribute is the best approach. Several steps can be taken to facilitate this, some of which originate from discussions within the stakeholder workshops that formed part of this project. Primarily, easy access to clear guidance and online mapping is a valuable tool to ensure stakeholders are well informed and confident in their decision-making. Secondarily, influencing changes to existing management practices such as branchage may be possible to generate benefits for wildlife. Thirdly, there are several strategies in place that can be unified to follow a common plan if guidance is provided, providing logistical and financial savings in the long-term. These include efforts by local organisations to improve habitat, such as hedgerow planting schemes by Jersey Trees for Life and winter crop planting by Birds on the Edge. At a policy implementation level, the current plans for developing countryside access and the LEAF (Linking Environment And Farming) accreditation scheme can be joined with priorities for conservation. Current barriers to these approaches include difficulty in identifying and attributing land ownership in some areas (Department of the Environment 2016).

Limitations

The accuracy of both distribution and connectivity models are dependent upon the quality of occurrence data (i.e. the record is correctly identified and has a strong geographical accuracy). Furthermore, despite the efforts of a few dedicated individuals, many groups remain under-recorded (e.g. lichens, mosses, invertebrates), with few records available. We could have taken the approach to assume all records classed as 10–100m accuracy were also suitable for inclusion, but there is the possibility that this could introduce inaccuracies and bias model outputs. Instead, by overlaying records of lower accuracy it has been possible to quantitatively assess how the priority areas and corridors contribute to their coverage.

In addition, this study is heavily reliant on an accurate landcover map; however, habitats are not static entities (e.g. Penny Anderson Associates, 2015). This map was derived from Phase 1 data collected in 2010 and 2011, with the most recent aerial imaging to classify uncertain polygons having been recorded in 2013. There are constant changes in the landscape, often with conversion of arable or grassland landcover in to buildings and associated landforms (gardens, driveways, roads). Therefore, there will always be some inaccuracies. For instance, even if we updated the landcover map to a precise representation of the current landscape, as records have been collated from the last 10 years, there would be some mismatches between the habitats the species were recorded in during that period and the landcover type now mapped in that position. Given the overall small proportion of Jersey's landscape undergoing change however, it is unlikely this will have had a major impact on the landscape nor our findings. Moreover, areas predicted as suitable for protected areas or corridors can be ground truthed to ensure they still remain as suitable habitats. Similar issues arise due to a lack of data on the quality of many ecological components, such as hedgerows.

The broad classification of habitats to 23 landcover classes at a 25 metre resolution also introduces uncertainty. Of the landcover classes used, 'garden' incorporates a broad variety of habitats as they may range from paved or heavily modified barren areas to those of high habitat quality for biodiversity such as grassland to woodland. Therefore, the composition of gardens, particularly in unison, can be a positive or negative complement of the landscape depending upon their structure. Furthermore, assigning landcover classes to 25 metre cells based on the maximum coverage or a landcover type in that cell can lead to unexpected results, as demonstrated by toads being incorrectly predicted as having an affinity for hottentot fig. Overall, despite potential inaccuracies, by using a suite of species and incorporating landcover into the models, it is still likely we have been able to identify the areas in which important habitats occur.

This report does not aim to diminish the importance of habitats and areas not identified in this study. Indeed, appropriately managed agricultural land can provide important habitats. For instance, pasture is often a valuable habitat for a multitude of invertebrates and associated predators such as serotine bats (*Eptesicus serotinus*) (Robinson and Stebbings 1997).

Further research

A number of opportunities remain to inform future planning and environment decisions, and to test the findings of this report. Finer scale evaluation of barriers and connectivity would be valuable, particularly where corridors are predicted to cross roads. This could be carried out by evaluating wildlife road mortality and provide guidance on where wildlife crossings may be appropriate. Further validation of our proposed corridors can be carried out by utilising movement (e.g. radio-tracking) and genetic data of organisms to see how they disperse through the landscape. These approaches can also be used to monitor and evaluate the effectiveness of our recommendations when implemented.

The suite of species used in the species distribution modelling step consisted of relatively well recorded species; many of which were fairly widespread. The exclusion of many locally rare species was necessary due to a lack of records (recent or otherwise) and only a single or few localities. This limits the suitability of the data to be validated within MaxEnt and so predictions of landscape suitability cannot be evaluated effectively. Further data collection on these species may provide sufficient records for future work to conduct similar analyses.

The value of Jersey's landscape to natural capital and human wellbeing can also be incorporated in to future prioritisation strategies by conducting an evaluation of ecosystem services within the island including the potential for carbon storage, water purification, flood prevention, crop pollination, and benefits to mental and physical health. Similarly, consideration should be given over the contribution of natural areas to climate change resilience within the island.

Conclusions and recommendations

Jersey's wildlife occurs in a variety of habitats, with areas of high importance for connectivity and habitation centred within the west and southwest of the island, and the island's wooded valleys. Though existing protected areas provide support to Jersey's biodiversity, they only cover a small proportion of priority conservation areas and are therefore in need of expansion. Greater structure and support is needed to guide biological recording in the island in order to provide more complete datasets for future analyses of the island's conservation status. Improvements to the current ecological network should be combined with monitoring before and after implementation to assess the effects of any interventions. We provide the following recommendations:

1. Extend protection to HCAs currently unprotected and restore degraded habitats. High priorities are:
    - St Peter's Valley woodland
    - Waterworks Valley
    - Bellozanne Valley
    - La Vallée des Vaux
    - St Brelade's Valley woodland (from St Aubin to Pont Marquet along the railway walk)
    - Railway walk and surrounding areas (from La Corbière to Les Quennevais)

2. Maintain, and strengthen support for protection of areas within Jersey's National Park and restore degraded habitats. Based on our HCAs, high priorities are:
    - Les Mielles Nature Reserve
    - St Ouen's Bay escarpment
    - The coastal plain between Les Blanches Banques and La Mare au Seigneur, including Simon Sand and Les Mielles Golf and Country Club
    - Extension of Les Blanches Banques SSI on to La Moye Golf Course

3. Maintain protection of the existing SSI network.

4. Maintain, restore and where possible protect habitat along wildlife corridors identified to improve the function of Jersey's ecological network. High priorities include:
    - **St Brelade**
        - From La Corbière, eastward to St Brelade's Bay (A)
        - From west to east following the escarpment behind St Brelade's bay seafront (B)
        - Between Le Mont Sohier, Ouaisné, Portelet and Noirmont; linking these areas (C)
        - North from St Brelade's bay (midbay carpark) to the southeastern corner of the airport (D)
        - Along the southern edge of the airport through Les Ormes Golf Club and on to Les Blanches Banques (E)

- From above Pont Marquet (Maison St Brelade residential home), going west / northwest across the top of Les Quennevais and through Creepy Valley on to Les Blanches Banques (F)

- **St Peter / St Ouen**
  - North along St Ouen's bay escarpment and valleys and in parallel along St Ouen's Bay coastal plain from Les Blanches Banques to La Saline and Les Pres D'Auvergne (G)
  - From the wooded area along Route du Marais, south to La Ville au Bas (H)
  - Eastwards from Les Pres D'Auvergne to Route du Marais (I)
  - Northwest along the escarpment Les Pres D'Auvergne to Les Landes de l'Est (J)
  - From the wooded area along Route du Marais, northeast to Grève de Lecq and then west along the coast to Plémont (K)
- **Trinity / St Martin**
  - Between Rozel woods and Jersey Zoo (at the north-western tip of the woodland running from St Helier to Trinity) (M)
- **Grouville**
  - Through Grouville Marsh and parts of Royal Jersey Golf Club (N)
- **Island-wide**
  - Throughout the enclosed wooded valleys (L)

5. Provide financial and logistical support to the structured collection of biological records for future repeats of this and other analyses to assess the status and needs of Jersey's biodiversity.

6. Focus species monitoring on a small set of diverse species to provide thorough datasets for future analyses. We recommend inclusion of the following species:
   - Western toad (*Bufo spinosus*)
   - Common shrew (*Sorex coronatus*)
   - Lesser white-toothed shrew (Crocidura suaveolens)
   - Red squirrel (*Sciurus vulgaris*)
   - Beautiful demoiselle (*Calopteryx virgo*)
   - Black-backed meadow ant (*Formica pratensis*)
   - Glow worm (*Lampyris noctiluca*)
   - Ragged robin (*Lychnis flos-cuculi*)
   - Southern marsh-orchid (*Dactylorhiza praetermissa*)

- Autumn lady's-tresses (*Spiranthes spiralis*)
- Pepper Pot (*Myriostoma coliforme*)

7. Carry out monitoring to detect changes following improvements to connectivity.

8. Conduct detailed mapping and quality assessment of landscape features (e.g. hedgerows) currently contributing to landscape connectivity.

9. Engage stakeholders (e.g. land owners and managers) in conducting habitat improvements works by providing clear and accessible recommendations.

10. Incorporate priority conservation area recommendations in to LEAF accreditation and countryside access planning.

11. Inform island plan and terrestrial spatial planning.

12. Incorporate the findings of this report in to environmental and planning investigations such as EIAs and planning applications as an additional source of guidance for areas of environmental sensitivity.

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