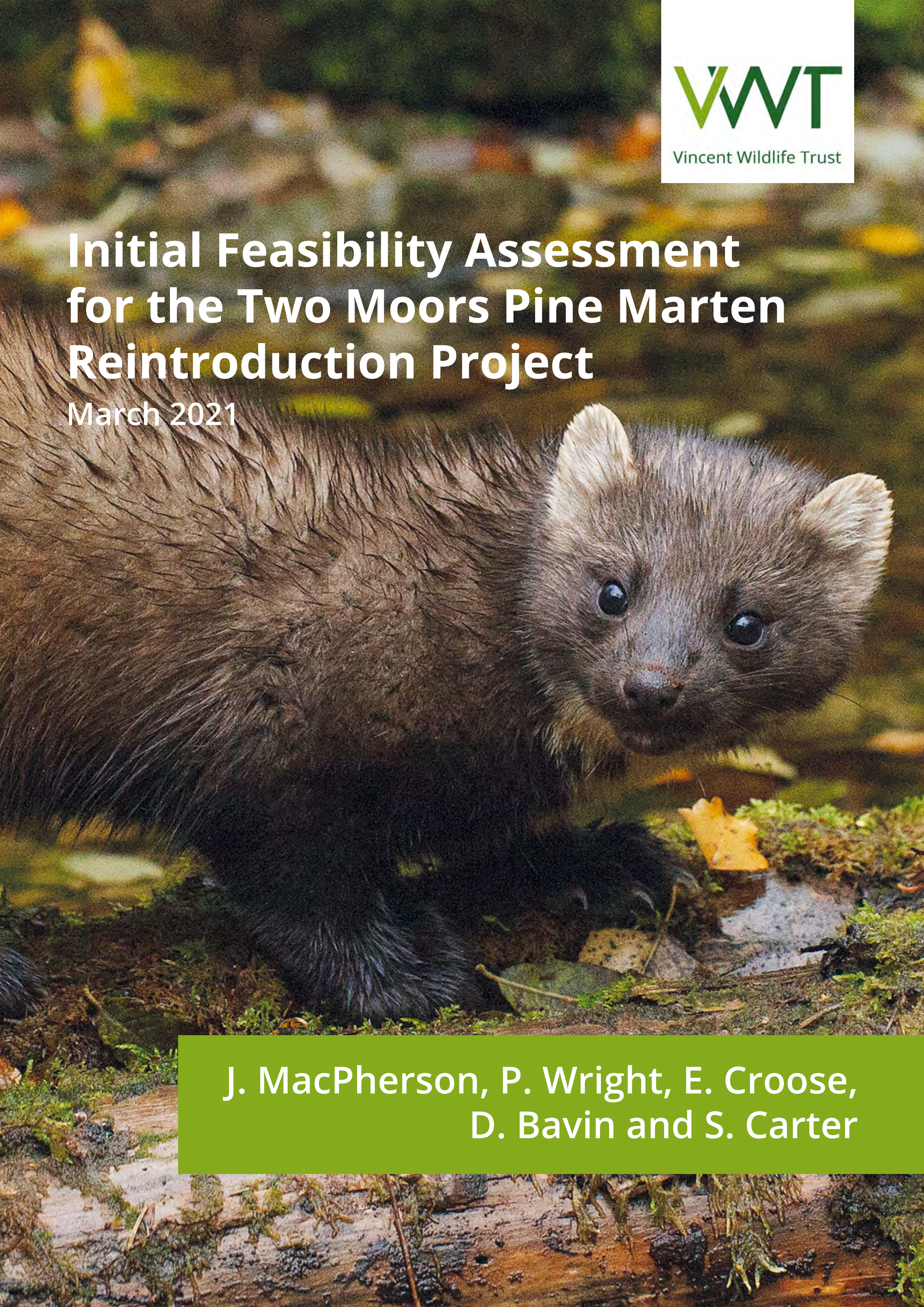
Vincent Wildlife Trust

Initial Feasibility Assessment for the Two Moors Pine Marten Reintroduction Project

March 2021



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Executive summary

The Two Moors Partnership is comprised of both Dartmoor and Exmoor National Park Authorities, The National Trust, Devon Wildlife Trust and the Woodland Trust. The partnership was formed with the aim of exploring the potential for restoring a viable pine marten *Martes martes* population to the wooded landscape across Somerset and Devon. Vincent Wildlife Trust (VWT) has carried out an initial feasibility study to assess the suitability of the Two Moors Project area for future pine marten reintroductions.

The preliminary feasibility assessment presented here suggests that a landscape-scale pine marten reintroduction project across Devon and Somerset merits further investigation. Modelling methods were used to assess habitat suitability and landscape connectivity across the region. The results of the most conservative models show that the large area of woodlands parallel to the northern coast of Somerset is the most contiguous region of highly suitable habitat for pine martens within the Two Moors Project area. There is also a large swathe of good habitat running south from Bideford to Holsworthy and then Okehampton. This is made up of a series of ‘stepping-stone’ woodlands that link the northern project area to that around Dartmoor in the south. Predicted suitable habitat is dispersed throughout the landscape although high traffic flows result in low habitat suitability in some parts of south Devon.

Our Circuitscape model suggests there is high connectivity across the landscape in north Somerset, northwest and south Devon, with some further west from southwest Devon into the border with Cornwall. Spatially explicit population viability analysis was used to compare the long-term predicted dynamics of a reintroduced pine marten population under three different scenarios. One where animals were reintroduced only into north Somerset, another where reintroductions took place in south Devon and a third where martens were reintroduced over two years into release sites in both counties. The results suggest that it is likely that a viable population would result from any of the three scenarios, but that a landscape-scale reintroduction project across both counties would result in a pine marten metapopulation with the most resilience. Two potential release regions are suggested, one to the north and east of Exmoor and the other to the east of Dartmoor.

We carried out an initial assessment of which other species of commercial or conservation concern might be impacted by a reintroduced pine marten population. Information from the Red and Amber List of birds in Britain was used to identify which species could be vulnerable to impacts from pine martens. For the majority of Red and Amber List species that breed in the Two Moors Project area, the proportion of their British breeding range contained in the region is negligible (<1%), so their breeding populations are not likely to be vulnerable to adverse impacts of pine marten predation. Cirl bunting *Emberiza cirlus* from the Red List, has a notable proportion (21%) of its British breeding range around Dartmoor and so could be vulnerable to impacts from any additional predation. However, as a farmland species, cirl buntings are extremely unlikely to be encountered by pine martens, which generally avoid open areas. Furthermore, the distribution of the cirl bunting and pine marten overlaps extensively in western and southern Europe, where the population is believed to be increasing.

The other species potentially of concern is the Dartford warbler *Sylvia undata*, an Amber List species, which breeds in both Dartmoor and Exmoor (comprising 4.7% and 4.03% of its British breeding range, respectively). In England, this species shows a negative response to the proximity of woodland which means that Dartford warblers and pine martens are unlikely to overlap in their habitat use. Pied Flycatcher *Ficedula hypoleuca*, is an Amber List species present in both Dartmoor and Exmoor. Nest box schemes in the region for this species and for hazel dormice *Muscardinus avellanarius* might need to be modified to prevent martens from accessing them. This should be discussed with the relevant stakeholder groups. A number of protected sites in the counties have bat species listed as designated features. Some bat species may be at risk from predation by pine martens, so it is important that any significant and accessible colonies of rare bats in the region are properly risk assessed and appropriate mitigation discussed and put in place where necessary. Species of economic importance must also be considered. There are a number of commercial shoots within the Two Moors Project area and it is recommended that these are engaged with at the outset.

Successful reintroductions must consider social, as well as biological feasibility in the context of the species, habitats and landscapes where they are being considered. Local support and stakeholder participation in the decision process is vital for the long-term establishment, particularly of a carnivore reintroduction. Both the IUCN Guidelines (IUCN 2013) and The Scottish Code for Conservation Translocations (2014) emphasise the importance of social and cultural considerations in species restoration. Identification of groups and individuals that may be affected by potential reintroductions is a vital element in ensuring reintroduction success. The original proposal was for VWT to initiate preliminary engagement with relevant stakeholders and local communities, working closely with local staff from the partnership. However, plans to undertake initial face-to-face engagement in 2020 were not possible, due to COVID-19 and associated restrictions. An altered approach was taken, whereby VWT ran online training workshops for relevant staff of the partner organisations covering key aspects of community and stakeholder engagement and consultation, based on VWT's experience.

During winter 2020/21, five workshops were run, cumulatively attended by 92 people from organisations within the partnership and some relevant external organisations and individuals. The content and focus of the discussion varied between the workshops, but the common themes and discussion points centred on potential impact of pine martens on potentially vulnerable prey species (Red and Amber List birds, bats, dormice) as well as game birds, and options for mitigation; pine martens and forestry/woodland management and how best to select and target stakeholders for engagement and consultation. The next step for the partnership should comprise focused engagement and consultation with relevant stakeholders and local communities in the potential release areas, to ascertain the social feasibility of a pine marten reintroduction.

The preliminary assessment carried out here suggest that the Two Moors Project area in Somerset and Devon warrants further consideration for a pine marten reintroduction, if other conditions are satisfied. This includes appropriate risk assessments for disease, as well as other species and habitats, minimal conflict with other land users and sufficient resources secured for a reintroduction and subsequent long-term monitoring and engagement.

1 Introduction

The Two Moors Partnership

The Two Moors Partnership was formed with the aim of exploring the potential for restoring a viable pine marten *Martes martes* population to the landscape in Somerset and Devon. The partnership, comprised of both Dartmoor and Exmoor National Park Authorities, The National Trust, Devon Wildlife Trust and the Woodland Trust, approached Vincent Wildlife Trust (VWT) for its expertise in this area. VWT agreed to carry out a study of the habitat suitability in and around the National Parks and other preliminary work on the potential for pine marten restoration in this area.

Objectives and geographical scope of the present study

The report presented here constitutes a preliminary feasibility assessment of the suitability of the Two Moors Project area (which encompasses both Dartmoor and Exmoor National Parks and the surrounding landscape. See Figure 1) for future pine marten reintroductions by:

- modelling and mapping potentially suitable pine marten habitat across south-west England, and using appropriate modelling methods to investigate population viability, potential carrying capacity and landscape permeability for future range expansion;
- discussing the potential ecological impacts that a reintroduced pine marten population may have on other species, and further work that may be required;
- providing information and good practice guidance for a full social feasibility assessment and a programme of stakeholder and community engagement;
- discussion of how the Two Moors Project might fit with a national long-term strategic recovery plan for the species.

The objectives at this stage were to determine whether, and where, further, more detailed assessment is warranted and, if so, to make recommendations as to how to progress towards the longer-term aspiration of the partnership to restore pine martens to their former range in southwest England.

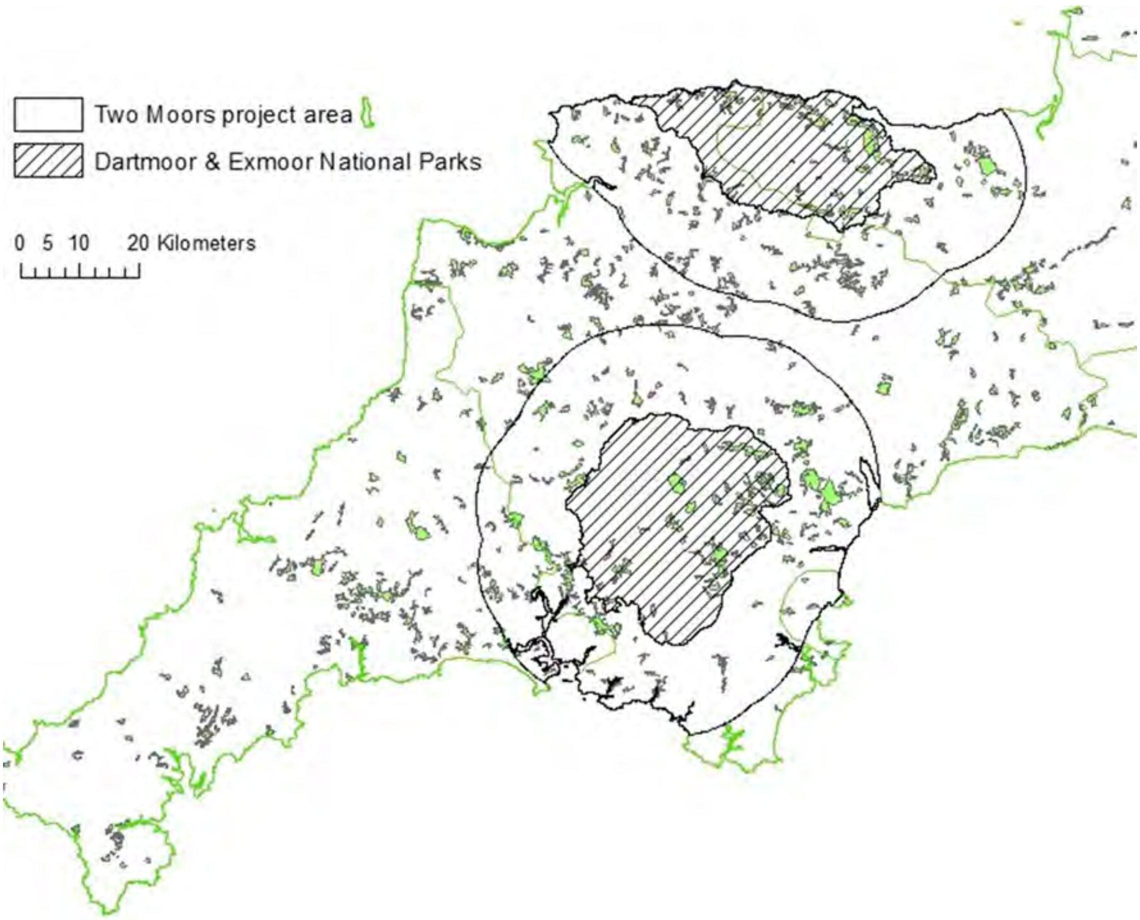

Figure 1 The Two Moors Project area comprising Exmoor (north) and Dartmoor (south) National Parks (hatched) and the surrounding woodlands.
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Background

The pine marten is a medium-sized member of the mustelid family, native to Britain and Ireland. Pine martens are distributed across Europe, where they are predominantly associated with forested habitat (Mitchell-Jones *et al*. 1999). The species was once common and widespread throughout Britain (Maroo & Yalden 2000), but during the 19th and early 20th centuries the population suffered severe declines in numbers and distribution. This was largely a result of increases in predator control (Langley & Yalden 1977; Tapper 1992), compounding the historical effects of loss and fragmentation of woodland habitat. By the beginning of the 20th century pine martens were extinct in almost all of southern Britain, with the majority of the remnant population restricted to the north-west highlands in Scotland, and much smaller areas in the uplands of northern England and Wales (Langley & Yalden 1977).

With increases in afforestation and legal protection, the pine marten population in Scotland has been recovering well and expanding its range since the 1980s, but this was not the case elsewhere in Britain. By 2010, after 30 years of research and surveys by VWT, there was no evidence of pine marten recovery in England and Wales.

After several years of preparation and research (Jordan 2011; MacPherson *et al*. 2014; Bavin *et al*. 2020), VWT began, in 2015, to translocate pine martens from Scotland to mid-Wales, with a total of 51 animals released across three years (MacPherson 2018). The released martens have established territories, are breeding successfully and the population is now expanding further afield (McNicol *et al*. 2020). In 2016, VWT began to collaborate on a project led by Gloucestershire Wildlife Trust and Forestry England to explore the potential for reintroduction of the pine marten to the Forest of Dean in Gloucestershire (Stringer *et al*. 2018). As a result of research and feasibility studies, the translocation of pine martens to the forest began in 2019, with the initial release of 18 animals and there are plans for further releases in autumn 2021.

The results of spatially explicit population viability analyses, incorporating translocations that have taken place to date, show that the re-established population in Wales in combination with the reintroduction in the Forest of Dean is likely to result in a robust western metapopulation of martens within approximately ten years of the first releases into mid Wales. However, there is no natural recolonisation of suitable habitats in southwest England or in the east of the country predicted within this time frame (MacPherson & Wright 2021).

Pine martens in southwest England

The pine marten is thought to have become extinct in Devon, Somerset and Cornwall between 1870-1880 (Langley & Yalden 1977). Nonetheless, occasional records of pine martens in these counties were documented in the early 20th century, including sightings near Paignton in 1918, Dartmoor in 1932, at Noss Mayo in 1952, and South Brent and Maristow in 1953 (Hurrell, 1954). It was suspected that these animals originated from escapes from fur farms and three animals were known to have escaped from a collection at Wrangaton in the 1940s (Hurrell 1954; Hurrell 1953, cited by Strachan *et al*. 1996). Furthermore, the closely related but non-native beech or stone marten *Martes foina* was imported from continental Europe and kept in fur farms in parts of Britain, including one in Moretonhampstead the 1940s and 1950s, and escapes from these farms and other private collections may have accounted for some records during the mid-20th century (Strachan *et al*. 1996). Nevertheless, and despite these records, there has been no evidence of a viable pine marten population in southwest England since the late 19th century.

In recent years, there have been occasional unequivocal records of pine martens in Devon and Cornwall. These include a pine marten road casualty near Christow (Devon) in 2019, another road casualty near Sithney (Cornwall) in 2019, and a camera trap record from near Bude (Cornwall) in 2015. The origin of these animals is unknown, however, it is probable that they originate from covert releases, either from animals translocated from elsewhere, such as Scotland, or from captive collections. This is especially likely given the large distance from the nearest known marten populations (in Hampshire, Wales or Shropshire) and evidence from elsewhere that pine martens are occasionally captured in Scotland and covertly relocated to other parts of the country. It is almost certain that these records represent single animals and there is no evidence that they comprise a viable population or that there has been any population recovery in southwest England.

The Two Moors Partnership believes that the reintroduction of the pine marten and its habitat requirements would be a useful driver for the improvement of existing habitats and the creation of new habitats within the national parks. This would result in the creation of more dynamic mosaics of open and woodland habitats that would benefit a range of other species.

The pine marten, as a charismatic, flagship species of diverse and extensive woodland, can help raise awareness of the importance of woodland and habitat connectivity in the context of reversing biodiversity loss and building resilience to climate change and interest in pine marten reintroduction to southwest England has been increasing in recent years. Because of the natural low densities and large home ranges of pine martens, such a project would need to be at the landscape scale across Devon and Somerset. The successful reintroduction of the pine marten would reinstate a fundamental and highly charismatic missing element of the natural heritage in the south west of England. It could bring multiple benefits to the organisations involved as a nature conservation partnership working at a landscape scale and provide a strong focus for the development of Nature Recovery Networks, particularly within the two National Parks.

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2 Biological suitability for pine marten reintroduction

Introduction

Conservation translocation is defined as the managed movement of animals or plants from one location to another to achieve a measurable conservation benefit for the population, species or ecosystem. This includes reinforcement, where you are adding to an existing (but often small) population; and reintroduction, to restore a species to part of its natural range from which it has gone extinct. In addition, the term also covers conservation introduction, or assisted colonisation, where the aim is to establish new populations of a species beyond what has previously been its natural range. Translocation for species reintroduction is increasingly being used as a conservation tool in spite of the often high associated risks and costs. Where natural recovery or recolonisation is unlikely and other options are limited, then reintroductions may be necessary. If this is the case, then an initial assessment should look at whether, and where, this is feasible and most likely to succeed.

In recent years, there has been an exponential increase in the number of conservation reintroductions worldwide (Seddon, Armstrong & Maloney 2007; Ewen *et al*. 2012). Previous reviews of the outcomes of conservation translocations have often reported low rates of success (Wolf *et al*. 1996; Fischer & Lindenmayer 2000), with low habitat suitability and poor release site selection frequently cited as reasons for failure (Wolf *et al*. 1996; Armstrong *et al*. 2002; Cook, Morgan & Marshall 2010). The conclusion, therefore, is that a significant effort should be put into evaluating suitable release areas before considering going ahead with translocations. Scientific uncertainty is an inevitable issue in reintroduction efforts because the species is being reintroduced into an environment that it does not currently occupy. It cannot be assumed that historical sites still contain suitable habitat and it may often no longer be appropriate to reintroduce within a species' former range (Seddon 2010). The more time that has elapsed between local extinction and proposed reintroduction, the more likely it is that the habitat will no longer be suitable. This means there is a need to evaluate habitat suitability regardless of historical occupancy. Sites should never be selected solely on the basis that a species used to be there or that the site looks right. While detailed knowledge of a species' ecology can provide information on the likely current suitability of a proposed release site, modelling enables that knowledge to be put into a landscape context, projected into a range of current and future scenarios and compared against a number of objectively assessed alternative sites.

Habitat Suitability Modelling (HSM) is a statistical technique that predicts the distribution of a species from environmental data and occurrence records. Habitat Suitability Models (HSMs) (Koreň *et al*. 2011; Bellamy, Scott & Altringham 2013) correlate a set of species presence locations with environmental covariates to estimate habitat associations. HSMs can be used to predict distributions or habitat suitability in unsurveyed areas and can also be a useful tool to help identify candidate reintroduction sites for endangered species (Martinez-Meyer *et al*. 2006; Osborne & Seddon 2012). MaxEnt (Phillips, Anderson & Schapire 2006b) is one of the most commonly used HSM techniques and has been used to model suitable habitat for various species (Phillips, Anderson & Schapire 2006b; Gibson, Barrett & Burbidge 2007; Ward 2007; Hernandez *et al*. 2008; Stabach, Nadine & Olupot 2009). It has been shown to perform better than other presence only and presence-absence modelling techniques (Elith *et al*. 2006; Hernandez *et al*. 2006).

Across Europe, the pine marten is associated with woodland habitat although, contrary to what their name implies, pine martens are not restricted to coniferous forest but will also use deciduous or mixed woodland. The main characteristics defining suitable habitat for pine martens are diversity of plant species as well as structural diversity. Martens are reported as using non-forest areas that provide sufficient structure as protective cover. These include brash piles in regenerating clear fell, as well as dense shrub and scrub. The pine marten's avoidance of open habitats relates to predation risk. In woodland, a dense shrub layer gives cover and trees provide a vertical escape route from potential predators, such as the red fox *Vulpes vulpes*. Natural cavities in mature trees are important den sites, particularly for breeding females, offering both thermal insulation and protection from predators for vulnerable kits. Vole-rich habitats such as scrub and tussocky grassland are important for hunting and foraging, and martens will make use of these habitats if they are in sufficiently close proximity to tree or hedgerow cover. Grassland habitat beside watercourses often support high densities of field voles *Microtus agrestis*, one of the pine marten's main prey, and can also be important habitat corridors. Pine martens do not utilise open habitats such as moorland and agricultural land. They are also known to avoid urban areas and anthropogenic structures. Roads are a significant cause of mortality for many carnivores and can present a barrier to dispersing pine martens.

Connectivity between suitable habitats is of vital importance in maintaining gene flow, social interaction (for example mating) within species, dispersal, range expansion and, ultimately, population persistence. In order to conserve species in increasingly fragmented landscapes, an understanding of how connectivity is affected by landscape features is needed. Many ways of predicting connectivity using landscape data have been developed recently, including connectivity models from electrical circuit theory. These can be used to model connectivity in ecology and conservation. We used Circuitscape (McRae & Shah 2009) methods to determine likely corridors and other important elements of the landscape connecting suitable habitat in southwest England for pine martens.

We used MaxEnt (Phillips, Anderson & Schapire 2006a) presence-only HSM to predict suitability of habitat for pine martens across southwest England. In the context of identifying suitable sites for reintroduction, the consequences of overestimating habitat suitability would be far worse than those of underestimating it. Therefore, to minimise the risk of false positives (Type I error), we used the most conservative model that we constructed. We then used outputs from the HSM in Circuitscape v4.0.5 (McRae *et al*. 2008) to map habitat connectivity for martens in Britain.

Population Viability Analysis (PVA) is a tool used to model population dynamics in specific scenarios. A PVA computer model combines life history and demographic data with environmental variability to estimate the probability that a population will remain viable over a given period of time (Bessinger and McCullough 2002). Spatially explicit PVA models incorporate geographic data into the model to identify areas of suitable habitat available to the members of a study species in a specific area. Three basic steps are involved when constructing a spatially explicit PVA model. First, GIS is used to analyse landscape data and delineate the habitat patch structure of the target species in the study area. Secondly the habitat data is combined with demographic parameters of the study species such as home range size, dispersal distance, survival and fecundity values, and sex and age structure. Finally, simulations are run to estimate rates of population decline or growth.

We carried out Population Viability Analyses using HexSim (Schumaker & Brookes 2018), a spatially explicit individual-based population model, to link landscape structure from the HSM with population dynamics. We used HexSim to run a series of simulations to look at likely patterns of pine marten persistence, dispersal and range expansion, both at a national scale with and without translocations and, at a finer scale, to further investigate the potential of southwest England as a reintroduction region.

Methods

Habitat suitability modelling

We used MaxEnt (Phillips, Anderson & Schapire 2006a), a presence-only HSM approach, to predict suitability of habitat for pine martens. All analyses were carried out using R (v. 3.5.3; R Core Team 2013) in R Studio (v.1.2.5042; RStudio Team). Presence records consisted of pine marten scats, confirmed by DNA testing, which had been collected during recent surveys between 2012-2013 in Scotland (for details see Croose, Birks and Schofield 2013). Additional confirmed pine marten records from the 'Back from the Brink' project in northern England were also included in the analysis. We also obtained pine marten records in Scotland from the GBIF database (https://www.gbif.org/) where only records of a sufficient resolution dating from 2005 onwards were kept. Once all presence records were collected, we filtered records to retain a single record per grid square. The HSM used records from Britain only and the landscape variables used were derived from Wright *et al*. (2020) (Table 1). This model was constructed with fewer records than if we had included data from Ireland or continental Europe, where there are subtle differences in marten ecology and they may occupy a slightly different niche from that in Britain. It does, however, provide important information on the impact of road density and traffic on pine marten presence in Britain.

Table 1 List of environmental predictors used for HSM model.

Explanatory variable	Source
All road traffic	GB Road Traffic Counts (data.gov.uk, 2019)
B-road density	OS Open Roads (2019)
Major road density	OS Open Roads (2019)
Major road traffic	GB Road Traffic Counts (data.gov.uk, 2019)
Minor road density	OS Open Roads (2019)
Minor road traffic	GB Road Traffic Counts (data.gov.uk, 2019)
Coastal habitat (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Heathland (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Natural grassland (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Pasture (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Scrub (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Woodlands (% cover)	CORINE LC 2018 (Aune-Lundberg and Strand 2010)
Arable (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Broadleaved (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Coniferous woodland (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Urban (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Improved grassland (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Rough grassland (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)
Freshwater (% cover)	Land Cover 2007 (Morton, Rowland et al. 2011)

All explanatory variables were measured at two candidate scales—1 km and 3 km. The optimal scale was identified for each predictor by creating univariate models using default settings with threshold features disabled (Hijmans *et al*. 2017; Bellamy et al. 2020; Wright *et al*. 2020). The scale with the highest training gain measure was then selected (Merow, Smith & Silander Jr 2013).

For each model, we removed highly correlated variables using the ‘vifstep’ stepwise function of the ‘usdm’ package (Naimi *et al*. 2014) and a conservative VIF threshold of three (Zuur, Ieno & Elphick 2010). We used the package ‘ENMeval’ (Muscarella *et al*. 2014) to identify the optimal MaxEnt model settings. We tested combinations of feature types (L, linear; H, hinge; Q; quadratic; P, product) and disabled threshold features to reduce overfitting. We varied the regularisation multiplier in steps of 0.5, from 0.5 to 4. Then, we performed a final model using the optimal settings to produce model predictions. Model fit was assessed using Receiver Operator Characteristic (ROC) curve analysis and the Area Under the Curve (AUC) values. An AUC greater than 0.9 is classed as very good, with 0.7-0.9 being good, and an AUC of less than 0.7 classes as uninformative (Swets 1988).

Connectivity modelling

We used Circuitscape v4.0.5 (McRae & Nürnberger 2006), a software linking circuit and random walk theories, to visualise the amount of connectivity for pine martens in south-west England (2km resolution) and Britain (5km resolution). As opposed to least-cost-path analysis, Circuitscape calculates all possible pathways connecting points (or habitat patches) through the landscape based on a resistance surface and provides a current map identifying areas of high connectivity in the landscape.

Here, the resistance surfaces were based on the pine marten HSM. To transform the habitat suitability values into a resistance surface, we used a negative exponential function where c=32 (Trainor *et al*. 2013; Mateo-Sánchez *et al*. 2015; Keeley, Beier & Gagnon 2016):

$$R=100-99\,(1-\exp(-cH))/(1-\exp(-c))$$

H=habitat suitability value c=32

We used the suitable habitat patches identified from each HSM as the focal nodes, and the pairwise modelling mode which calculates movement probability between all possible pairs of habitat patches.

Population Viability Analyses

HexSim is a life history simulator used for building population viability models, but also looking at interactions, and responses to disturbance. These models are spatially explicit and individual-based. Individuals can be assigned dynamic life history traits. In these simulations, we investigated the population viability and potential spread of pine martens over a 50-year period after proposed reintroductions in southwest England.

We ran the models for three different scenarios, where we tested reintroducing individuals at a single site in north Somerset, a single site in south Devon and reintroducing individuals simultaneously across both sites. The first two models consisted of reintroducing eight males and eight females each year for two years (N = 32), while the third model reintroduced ten males and ten females in each of the first two years (N = 40). Previous PVA suggests that pine marten reintroductions should consist of a minimum of 30 animals and that an equal sex ratio is optimal (Bright & Harris 1994). The models were designed to replicate as much as possible the life history of pine martens (home range, dispersal, survival, etc. parameter values taken from Powell *et al*. (2012)). The hexagon size was set at 25 ha and values from the HSM ranged between 0 and 100. Other settings are listed in Table 2.

Table 2 Summary of settings and values used to set the home range of individual pine martens.

Setting	Value
Maximum Range Area	120 hexagons (30km^2)
Minimum Range Resource	800 (equivalent to 2km^2 of very good habitat)
Female Resource Target	(Maximum Territory Size x [(MTSS+10th percentile0/2]) +600
Male Resource Target	Female Resource Target x 2
High Resources Threshold	MTSS value from the HSM
Medium Resources Threshold	10th percentile threshold

Results

Habitat suitability modelling

The final model (LQHPT-2) used 1,808 pine marten records and had an AUC of 0.93 (average AUC = 0.91 ± 0.002 using threefold cross validation). The probability of pine marten occurrence was mainly characterised by reduced road traffic (permutation importance: 30.9 %; 1km scale) and high coniferous woodland (23.7 %; 3km scale) and woodland cover (20.7 %; 3km scale) (Figure 2).

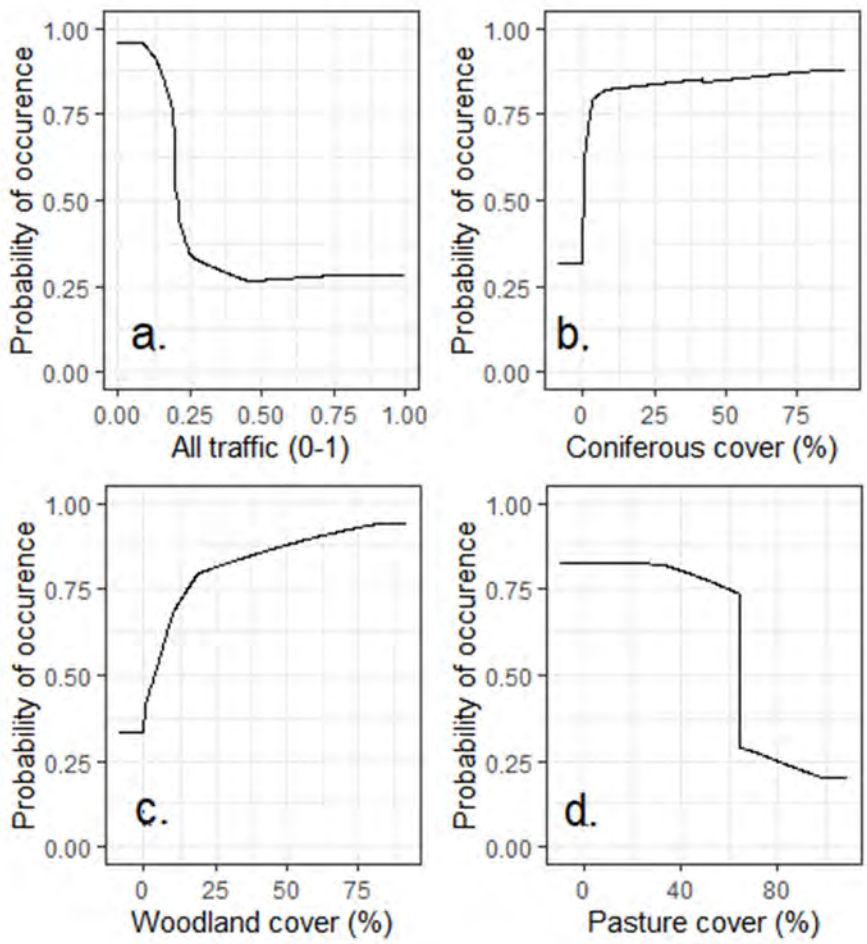

Figure 2 Response curves of the four variables showing the highest permutation importance for pine martens. Response curves are plotted from the most important (a) to the least important (d) permutation importance.

Areas of suitable habitat were primarily identified in Scotland, northern England and Wales. Other areas were identified in southwest England, but also in East Anglia (Figure 3). Most of England, however, remained largely unsuitable (Figure 3).

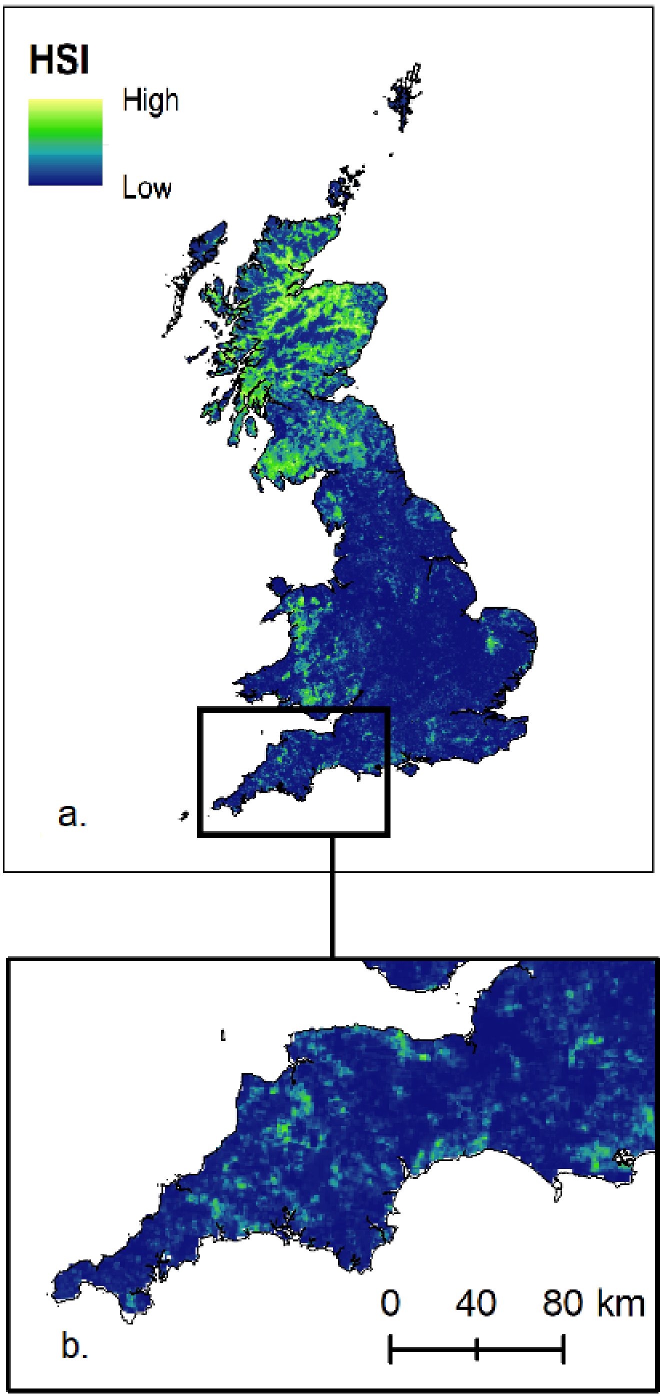

Figure 3 Logistic output of the HSM model
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Table 3 Predictor contribution values. Any missing variables from Table 1 were removed due to multicollinearity.

Environmental variable	Optimal scale (km)	Permutation importance (%)
All road traffic	1	30.9
Coniferous cover	3	23.7
Woodland cover	3	20.3
Pasture cover	3	8.4
Arable cover	3	7.9
Minor road traffic	3	3
Broadleaved woodland	1	1.7
B-road density	3	1.1
Improved grassland	1	1
Scrub cover	3	0.8
Rough grassland	1	0.5
Freshwater cover	3	0.4
Urban cover	3	0.3
Coastal habitat cover	1	0

In the southwest, areas of high suitability were associated with areas of high forest cover with the exception of south Devon, where the high levels of road traffic reduced the suitability of the habitat.

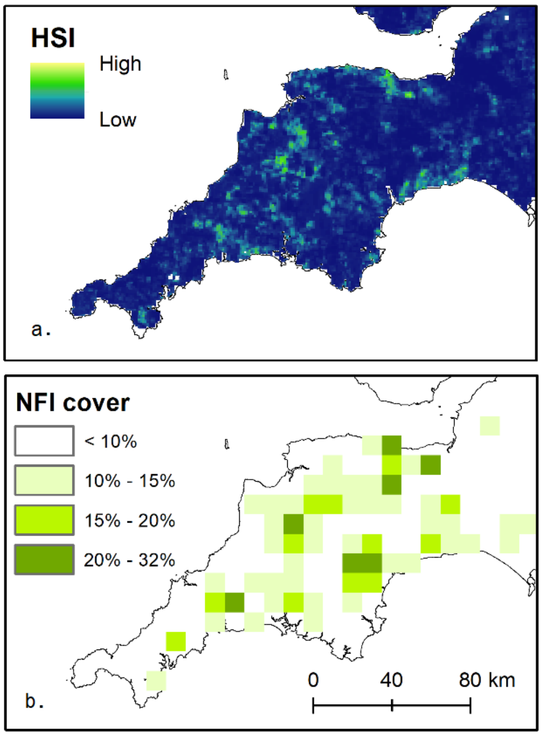

Figure 4 Comparison between the logistic output of model 2 (a) with the amount of woodland cover (c) according to the National Forest Inventory (Contains Forestry Commission information licensed under the Open Government Licence v3.0.).
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Connectivity modelling

The resistance surface had areas of high resistance throughout most of eastern England, while Scotland and Wales were mostly areas of low resistance, ie, good connectivity. We found low resistance values in southern England, while areas of high resistance extended throughout most of England (Figure 5). Habitat was more fragmented south of the Scottish border and connectivity was only preserved up to the Midlands. Some connectivity was observed in southern England and central and eastern England had low connectivity (Figure 5).

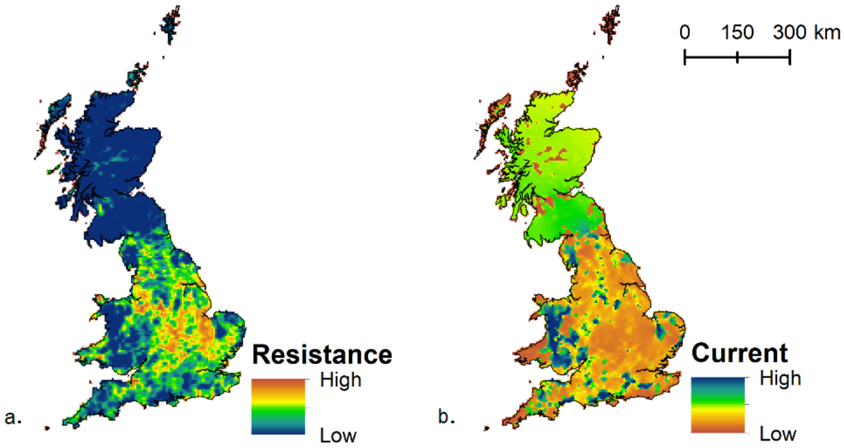

Figure 5 Resistance surfaces of Britain at a 5km resolution using the highest transformation (32) (a) and the Circuitscape output in the form of a current map representing the amount of connectivity between habitat patches (b).
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

In southwest England, high resistance values were mostly found in Somerset (Figure 6), but resistance also remained high in south Devon, west Cornwall and Dorset. Areas of high connectivity were mostly between west Somerset, north Devon and east Cornwall.

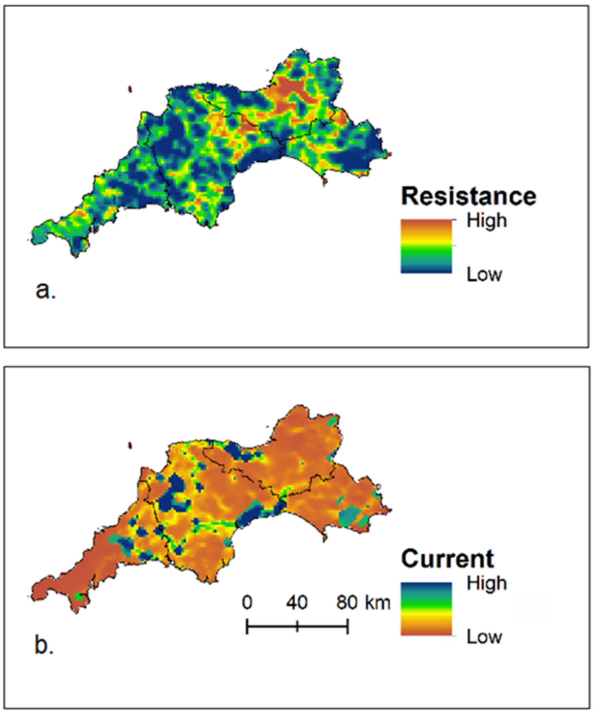

Figure 6 Resistance surfaces of southwest England (a) at a 2km resolution using the highest transformation (32) and the Circuitscape output (b) in the form of a current map representing the amount of connectivity between habitat patches.
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Population viability analyses

Home ranges ranged from $10km^2$ to $17km^2$ for males and 6 to $9.5km^2$ for females throughout all models (Figure 7a). Lifetime displacement, which represents the distance between the birth and death place of each pine marten and used a proxy for dispersal, varied mostly between 0 to 50km. Some individuals, however, would disperse over 100 km during their lifetime (Figure 7b).

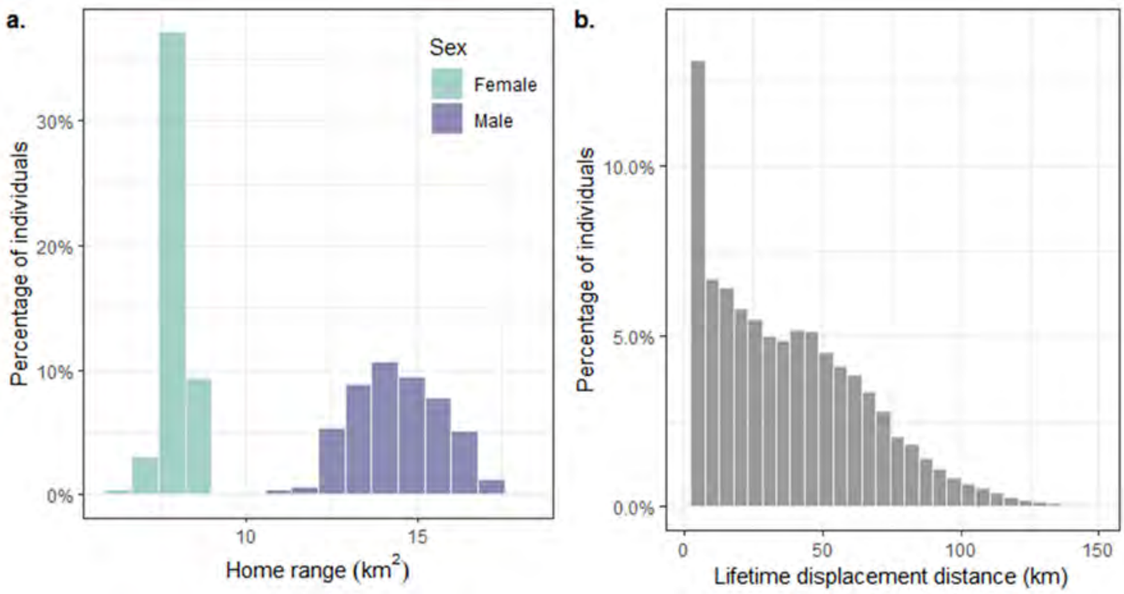

Figure 7 Distribution of home range (a) and lifetime displacement distance (b) of pine martens throughout all HexSim models.

The simulations showed that the mean population size did not exceed 75 and the slope varied from 0.61 to 0.74 between all three models (Figure 8). Reintroductions at both sites resulted in a more stable population, less susceptible to stochastic events (Figure 8c; Probability of extinction = 5%).

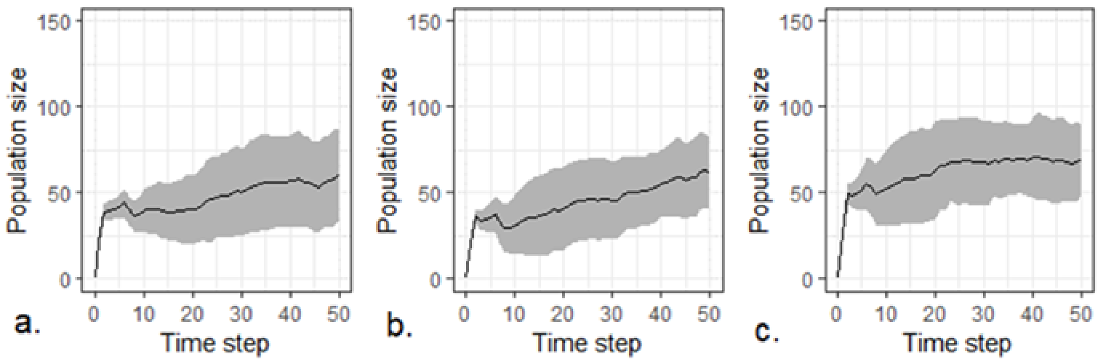

Figure 8 Summary of population trends (mean and standard deviation of all replicates) of each reintroduction strategy (Exmoor area releases – **a**; Dartmoor area releases – **b**; Releases across Exmoor and Dartmoor areas – **c**). Each time step in the model was equal to one year.

Discussion

Whilst there are no large blocks of forest in the southwest that are of comparable size to those in Scotland and Wales, the counties of Somerset, Devon and Cornwall have relatively high percentages of woodland (7%, 9.9% and 7.5% respectively; Forest Research 2002) compared to the majority of the rest of England. The region also has a low density of roads (Department of Transport 2018). Predicted suitable habitat is dispersed throughout the landscape although high traffic flows result in the low habitat suitability scores seen in some of south Devon. Our Circuitscape model suggests there is high connectivity across the landscape in north Somerset, northwest and south Devon, with some further west from southwest Devon into the border with Cornwall. Spatially explicit population viability analysis was used to compare the long-term predicted dynamics of a reintroduced pine marten population under three different scenarios. One where animals were reintroduced only into north Somerset, another where reintroductions took place in south Devon and a third where martens were reintroduced over two years into release sites in both counties. The results suggest that it is likely that a viable population would result from any of the three scenarios, but that a landscape-scale reintroduction project across both counties would result in a (meta)population with the most resilience. The results suggest that the counties of Devon and Somerset could be suitable for a future reintroduction project, subject to more detailed investigation of other factors. These include field surveys to assess prey availability, more detailed assessment of the potential impacts on other protected species and habitats, as well as the potential for conflict with other land users.

When considering a potential reintroduction, it is important to consider not only the characteristics of a specific area, but also the dispersal potential of the landscape that surrounds the area of interest. Suitable habitats in Somerset and Devon are in sufficiently close proximity to the restored populations in Wales and Gloucestershire for there to be a reasonable expectation of gene flow between them in the future, should a reintroduction go ahead in the southwest. HexSim models incorporating the southwest illustrate predicted occupancy across the region, as shown in Figure 9.

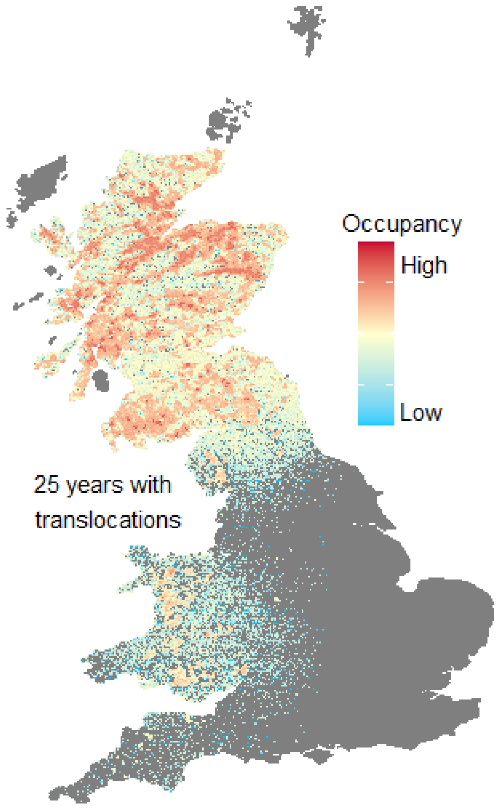

Figure 9 HexSim predictions of pine marten occupancy within 25 years of first translocations to Wales (in 2015), incorporating subsequent reintroductions to Gloucestershire and southwest England.
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The preliminary analyses carried out here suggest that the Two Moors Project area in Somerset and Devon warrants further consideration for a pine marten reintroduction, if other conditions are satisfied. This includes appropriate risk assessments for disease, as well as other species and habitats, minimal conflict with other land users and sufficient resources secured for a reintroduction and subsequent long-term monitoring and engagement. The socio-economic context, specifically human attitudes, is fundamental to the success of carnivore reintroductions and its importance cannot be underestimated.

Recommended Potential Release Regions (PRRs) for further investigation

Some larger areas of woodland in this region may be suitable as potential release regions (PRRs), and should be a focus for further work. Ideally, release sites should be in areas of extensive woodland, where pre-release pens can be sited away from the risk of human disturbance. The first animals to be released into an area where there is no established marten population are more likely to leave the release site and make longer distance exploratory movements (McNicol *et al*. 2020). For this reason, release sites should be within regions of high woodland cover (≥20%) and low road density. Based on these criteria and the results of our habitat suitability model, we identified two PRRs to be the focus for further work. These are both blocks within the Two Moors Project area, each consisting of nine contiguous 10km squares with at least 20% woodland and predicted high habitat suitability for martens, shown in Figure 10. The PRRs contain some of the largest single blocks of woodland within the project area.

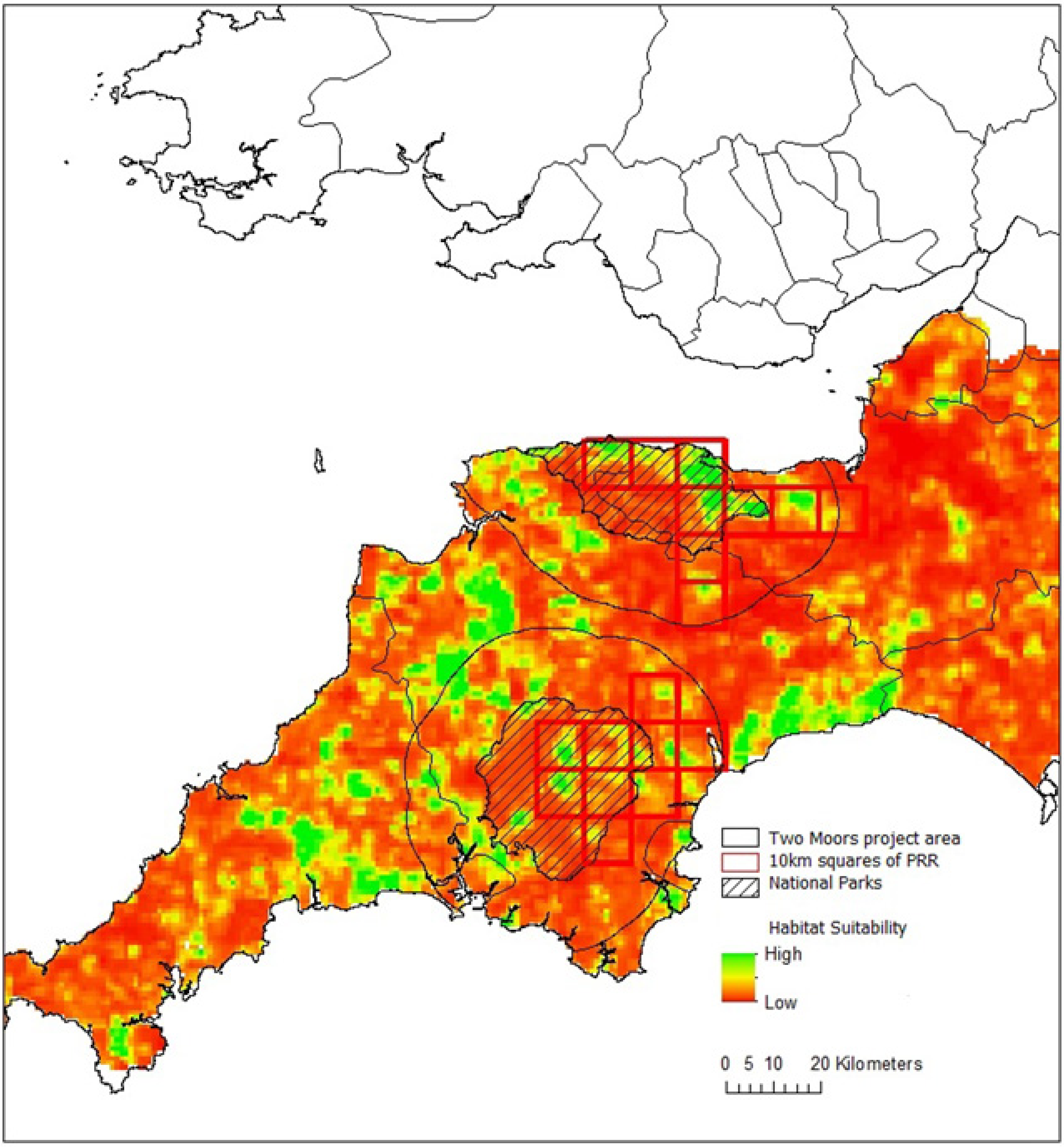

Figure 10 Potential Release Regions (PRRs) within the Two Moors Project area.
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3 Potential impacts of restored pine marten populations on other species

Introduction

Over the last century or more, the composition of ecosystems and distribution of wildlife species in Britain has changed dramatically. While numerous species have declined or been extirpated altogether, others have experienced population recovery. The costs or risks of any reintroduction (such as potential effects on species of concern) must be considered alongside the benefits (eg, improving conservation status, restoring ecosystem function). Reintegrating the pine marten into the ecosystems of southwest England requires consideration of how that might affect other species of concern. This section of the feasibility study includes an evaluation of the ecological roles of translocated animals in their new environment, and potential impacts on the conservation interests of other species already present in PRRs, as recommended by IUCN guidelines (IUCN 2013).

There is a perception that the recovery or restoration of a native predator may have a negative effect on native prey species, and this is a major concern for some stakeholders. Introduced, non-native predators can have a devastating effect on naïve prey populations, but when predators and prey have co-evolved over a long period of time, prey species adapt (behaviourally or morphologically) to reduce the rate of encounters with predators or increase their prospects of escape if detected (Lima & Dill 1990). The question of how predators impact numbers of prey has been extensively studied in many bird populations (eg, Newton (1993)). Whilst some studies have found a negative correlation between predator numbers and prey populations (Tharme *et al*. 2001; Fletcher *et al*. 2010; Smith *et al*. 2010), others show that presence or numbers of predators have no effect on prey numbers (Bolton *et al*. 2007; Holt *et al*. 2008). When the number of prey removed is offset by density dependent increases in the productivity of prey populations, then predation is compensatory. Predation simply replaces other causes of mortality and there is no overall impact on the prey population. However, if there is no density dependent compensation then mortality from predation is additive and will result in a reduction in prey population size. Mortality is often compensatory in the case of native predators, but is likely to be additive as a result of non-native predators (Holt et al. 2008).

When predators are at low densities and there is sufficient suitable habitat then prey can make use of ‘refuge’ areas that are temporarily predator free (Wirsing, Cameron & Heithaus 2010). When there is an alternative preferred prey or food available and this is abundant, then there may be little direct predation upon less preferred prey species (Tschanz, Bersier & Bacher 2007). This will particularly apply if predators are limited by density dependent effects, so that the abundance of one prey species does not result in increased predator density for other prey species. Nonetheless, for prey species that have already suffered significant declines as a result of habitat loss, fragmentation and other factors, even slight changes in predation rate may be catastrophic. This means that in some circumstances the recovery of a formerly very rare native predator could have a negative impact.

Populations of many wild birds in the UK have undergone steep declines over the past 40 years (Baillie *et al*. 2009), including woodland specialists and long-distance migrants (Gregory *et al*. 2007; Hewson & Noble 2009). The most vulnerable life history stage for most bird populations is the egg and nestling stage (Lima 2009). Adult birds can escape predation by flying, but they cannot move their eggs and so their ability to compensate for predation risk by avoidance is limited once they have committed to a nest site (Cresswell 2011). It has been suggested that increasing rates of nest predation could be a possible cause of the observed declines in UK bird populations (Fuller *et al*. 2005), although studies of individual species (Siriwardena 2004; Siriwardena 2006) and broad-scale surveys of changes in woodland birds (Amar *et al*. 2006, Newson *et al*. 2010b) do not support this.

A review of pine marten diet across its geographical range found that small mammals (<150g), are the most important food for pine martens in the temperate zone, making up an average of 50% of the diet at 50-60° north (Zalewski 2005). The proportion of birds in the diet varies seasonally across the range. It is higher in spring and summer, but also increases with latitude (Zalewski 2005). In Britain, pine martens show a preference for field voles, (Balharry 1993; Halliwell 1997) independent of their relative abundance locally, but switch to fruits when they are available in the autumn, with birds and other supplementary prey being taken mainly in summer (Caryl *et al*. 2012).

Here we assess overlap of the UK breeding distribution of rare bird species that might be predated by them, with PRRs for pine martens in the Two Moors Project area of Devon and Somerset (as shown in Figure 10). The implications are discussed along with other wildlife that may be affected by an increase in pine marten numbers, as well as recommendations for mitigation measures and future monitoring.

Methods

Potential impacts on rare or declining bird species were assessed for two regions in Devon and Somerset that are currently being considered for pine marten reintroductions. The Red and Amber Lists of bird species of conservation concern (Eaton *et al*. 2015) were used to identify which species had a breeding distribution in the UK that overlapped with potential reintroduction sites. Red Listed species are those that are recognised as being Globally Threatened using IUCN criteria, have suffered a severe decline in the UK between 1800 and 1995, without substantial recent recovery, have undergone a severe long-term decline in the UK breeding or non-breeding population size or have shown a reduction of more than half in the number of 10km squares occupied by breeding birds in the UK over 25 years or more. Species on the Amber List are those that are categorised as a Species of European Conservation Concern, were previously on the Red List but have more than doubled in the last 25 years or have undergone a moderate (more than 25% but less than 50%) decline in the breeding or non-breeding population or range. Other criteria are rarity, for species with a UK breeding population of fewer than 300 pairs, or non-breeding population of fewer than 900 individuals, localisation (at least 50% of the UK breeding or non-breeding population found in 10 or fewer sites) and international importance where at least 20% of the European breeding or non-breeding population is to be found in the UK.

Information on Red and Amber List birds in Britain was derived from the 2007-2011 *Atlas of Breeding Birds* (Balmer *et al*. 2014). Species from both Red and Amber List categories which could be potentially vulnerable to impacts from pine marten predation were identified as follows. Firstly, species that nest in woodland, woodland edge or habitats likely to be adjacent to woodland, and therefore likely to overlap with pine marten occurrence, were identified. Secondly, the breeding distribution of each of these species was derived from data provided by the 2007-2011 *Atlas of Breeding Birds* (Balmer *et al*. 2014). The number of 10km grid squares in which each species was recorded as breeding nationally in mainland Britain and the number within each of the Two Moors PRRs were identified. This was used to calculate the proportion of each species' total breeding distribution that was within the PRR. The species for which more than 5% of their British breeding distribution was within the PRR were classified as potentially vulnerable.

Results

Of the 163 species on the Red and Amber List, 62 species (35 Red and 27 Amber) nest in woodland, woodland edge or habitats likely to be adjacent to woodland. Of these, 41 species (23 Red, 18 Amber) are recorded as confirmed, probable or possible breeding in one or more 10km squares in the Two Moors PRRs (see Table 4).

There is one species for which more than 5% of its British breeding distribution is within the PRRs: cirl bunting *Emberiza cirlus*, which has 21.43% of its British breeding range within the Dartmoor region. Cirl bunting are not present in Exmoor. The red-backed shrike *Lanius collurio* was recorded as breeding in one 10km square within the Dartmoor PRR, constituting 8.33% of its British breeding range, according to data from the 2007-2011 *Atlas of Breeding Birds*. However, more current information considers that the red-backed shrike is effectively extinct as a breeding bird in Britain and is only present in the summer as a migratory visitor (RSPB 2020a) and as such, it is not classed as vulnerable in this assessment. The Dartford warbler *Sylvia undata* breeds in both Dartmoor and Exmoor, with just under 5% of its British breeding range falling within these regions (4.7% and 4.03%, respectively). For the remaining Red and Amber List species breeding in the region, the majority have less than 1% of their British breeding range in either of the PRRs (see Table 4).

Table 4 Red and Amber List bird species recorded as confirmed, probable or possible breeding in one or more 10km squares in the Two Moors potential release regions.

Species	Red or Amber List	Nest habitat type	% of British breeding distribution in Exmoor PRR	% of British breeding distribution in Dartmoor PRR
Cirl bunting *Emberiza cirlus*	Red	Hedge or scrub	0	21.43
Common cuckoo *Cuculus canorus*	Red	Parasitic	0.38	0.38
Common starling *Sturnus vulgaris*	Red	Tree hole or building	0.36	0.36
Eurasian curlew *Numenius arquata*	Red	Ground	0.12	0.06
Grasshopper warbler *Locustella naevia*	Red	Dense vegetation	0.3	0.42
Lesser redpoll *Acanthis cabaret*	Red	Tree nesting	0.58	0.45
Lesser spotted woodpecker *Dendrocopos minor*	Red	Tree cavity	0.54	1.25
Linnet *Linaria cannabina*	Red	Low in bush	0.37	0.37
Marsh tit *Poecile palustris*	Red	Tree hole	0.84	0.75
Merlin *Falco columbarius*	Red	Ground, cliff or nest of other bird	0.6	0
Mistle thrush *Turdus viscivorus*	Red	In major fork of old tree	0.37	0.37
Northern lapwing *Vanellus vanellus*	Red	Ground	0	0.19
Pied flycatcher *Ficedula hypoleuca*	Red	Tree hole or nestbox	1.50	1.50
Red-backed shrike *Lanius collurio*	Red	Small trees or bushes	0	0.83
Ring ouzel *Turdus torquatus*	Red	Ground, in mature heather, under bracken, on rock ledges or slopes	0	0.94
Skylark *Alauda arvensis*	Red	Ground among vegetation	0.33	0.33
Song thrush *Turdus philomelos*	Red	Tree nesting	0.34	0.34
Spotted flycatcher *Muscicapa striata*	Red	Tree nesting	0.41	0.41

Species	Red or Amber List	Nest habitat type	% of British breeding distribution in Exmoor PRR	% of British breeding distribution in Dartmoor PRR
Tree pipit *Anthus trivialis*	Red	Ground	0.63	0.63
Turtle dove *Streptopelia turtur*	Red	Bush or low trees	0.16	0.64
Willow tit *Poecile montana*	Red	Tree hole	0.18	0.72
Wood warbler *Phylloscopus sibilatrix*	Red	Ground	0.87	0.87
Yellowhammer *Emberiza citrinella*	Red	Ground or just above	0.41	0.46
Bullfinch *Pyrrhula pyrrhula*	Amber	Bush or scrub	0.39	0.39
Common kestrel *Falco tinnunculus*	Amber	Cliff edge	0.37	0.37
Common quail *Coturnix coturnix*	Amber	Ground under cover	0.46	0
Common redshank *Tringa totanus*	Amber	Ground	0.10	0.10
Common redstart *Phoenicurus phoenicurus*	Amber	Tree hole or stump	0.79	0.70
Common sandpiper *Actitis hypoleucos*	Amber	Ground in vegetation	0.08	0.08
Common swift *Apus apus*	Amber	Building, tree hole, nestbox	0.42	0.42
Dartford warbler *Sylvia undata*	Amber	near ground in dense vegetation	4.03	4.70
Dipper *Cinclus cinclus*	Amber	Cup nest on ledge over water	0.69	0.62
Dunlin *Calidris alpina*	Amber	Ground in tussock	0	0.47
Dunnock *Prunella modularis*	Amber	Cup nest in bush	0.34	0.34
European nightjar *Caprimulgus europaeus*	Amber	Ground near dead wood	1.23	2.16
Meadow pipit *Anthus pratensis*	Amber	Ground near vegetation	0.35	0.35
Red grouse *Lagopus lagopus*	Amber	Ground under cover	0	0.47
Short-eared owl *Asio flammeus*	Amber	Ground	0.24	0
Stock dove *Columba oenas*	Amber	Tree cavity	0.47	0.47
Tawny owl *Strix aluco*	Amber	Tree cavity	0.41	0.41
Willow warbler *Phylloscopus trochilus*	Amber	Ground against low bank or mound	0.34	0.34

Discussion

For the majority of Red and Amber List species that breed in the Two Moors potential release regions, the proportion of their British breeding range contained in the region is negligible (<1%), so their breeding populations are not likely to be vulnerable to adverse impacts of pine marten predation. Cirl bunting is the only Red List species which has a notable proportion (21%) of its British breeding range within the Dartmoor PRR and thus could be vulnerable to impacts from any additional predation. Restricted to the south coast of Devon and Cornwall and following population declines attributed to agricultural intensification, the cirl bunting population fell as low as 188 pairs in 1989, but has since increased to 860 pairs in 2012 (RSPB 2020b). Cirl buntings typically occur on traditional mixed farmland, nest in hedges (RSPB 2020b) and prefer to forage on stubble or fallow fields (Evans & Smith 1994). As such, they are extremely unlikely to be encountered by pine martens, who generally avoid open areas (Balharry 1993; Goszczynski *et al*. 2007; Brainerd & Rolstad 2012; Caryl *et al*. 2012). Furthermore, the distribution of the cirl bunting and pine marten overlaps extensively in western and southern Europe, where the population is believed to be increasing (BirdLife International 2020).

The other species potentially of concern is the Dartford warbler, an Amber List species, which breeds in both Dartmoor and Exmoor (comprising 4.7% and 4.03% of its British breeding range, respectively). In England, this species is found in shrub-dominated vegetation, almost exclusively dry lowland heath, and has shown a negative response to the proximity of woodland (van den Berg et al. 2001). This averseness to woodland means that Dartford warblers and pine martens are unlikely to overlap in their habitat use.

Pine martens, in common with many generalist predators, have a preferred prey species that maximises ease of capture and body size (Roth, Lima & Vetter 2006). In Britain, the field vole is the predominant small mammal in the pine marten's diet (Lockie 1961; Velander 1983; Balharry 1993; Gurnell *et al*. 1994; Halliwell 1997; Coope 2007; Caryl *et al*. 2012). A combination of their size, clumped distributions and relative lack of anti-predator behaviours makes field voles a profitable prey (Balharry 1993). In many years field voles are hugely abundant, although there is evidence to suggest that, where vole populations go through pronounced cycles, their proportion in marten diet varies more widely than where they are only weakly cyclic (Goszczynski 1986).

One of the concerns in Britain is that pine martens would switch to rarer alternative prey during years of low vole densities. Field voles in Britain do undergo population cycles (Charles 1981; Lambin *et al*. 1998), although these are much less pronounced than those in Fennoscandia (Lambin, Petty & Mackinnon 2000). When or where field voles are at low density in Scotland, the alternative foods recorded as being taken have been predominantly invertebrates (Balharry 1993; Bright & Smithson 1997), but also passerine birds (Bright & Smithson 1997). However, even during rodent population crashes in Bialowieza, Poland, Zalewski, Jedrzejewski and Jedrzejewska (1995) found that alternative prey formed a much smaller proportion of the diet than rodents. They therefore considered it unlikely that significant declines of alternative prey would be observed, even during times of rodent scarcity.

Pine martens take rare prey species only opportunistically as they encounter them, so prey vulnerability will be related to the amount of time pine martens spend in the same habitat as the prey. A species' vulnerability to predation by pine martens will also depend on a number of other factors, including its breeding biology, population density, anti-predator strategies and the availability of alternative prey. In addition to this, there will be interactions with other predators, with which pine martens are competing for resources. When a range of predators is present, as well as interference competition between predators, there may also be intra-guild predation of the predators themselves (Polis, Myers & Holt 1989). The general perception is often that there will be additional mortality for prey species if pine marten numbers increase. However pine martens might have a negative impact on other nest predators, such as corvids and grey squirrels *Sciurus* *carolinensis* (Sheehy & Lawton 2014; Sheehy *et al*. 2018), and may consume prey that would otherwise have been eaten by other predators. Food webs are highly complex and predator impacts are rarely as simple as generally perceived.

Breeding bird populations are able to mitigate against increasing predation pressure by mechanisms such as compensatory reduction in mortality rates from reduced competition for resources, and the recruitment of surplus, non-breeding individuals (Newton 1993). While there is some evidence for predators having an impact on populations of passerines (Stoate & Szczur 2001; Stoate & Szczur 2006), ground nesting waders and game birds (Tapper, Potts & Brockless 1996), previous analyses of UK national bird monitoring data, focusing in each case on a single predator species, could not detect any marked effects (Gooch, Baillie & Birkhead 1991; Thomson *et al*. 1998; Summers *et al*. 2004; Chamberlain, Glue & Toms 2009).

If pine marten predation is in proportion to bird abundance, then significant impacts are most likely on commoner species such as blackbird *Turdus merula*. However, modelling has shown that, for there to be any impact on blackbirds, birds as a whole would need to constitute more than 30% of pine marten diet (Bright & Halliwell 1999), which is rarely the case. Even then, pine martens would only predate two blackbirds per km^2 per year, which, considering that woodland blackbird populations can number 60-100 per km2 (Bellamy *et al*. 2000), is unlikely to have an impact.

Habitat loss and fragmentation may compound the impact of predation and its effects on prey. Reduced habitat heterogeneity may limit the capacity of prey to evade predation (Trussell, Ewanchuk & Matassa 2006). There can be a high level of spatial variability in predation as a result of heterogeneity in the landscape where predator and prey interact (Kauffman *et al*. 2007). It has been suggested that observed declines in farmland birds in the UK may be partly due to changes in habitat which have left bird species less able to effectively manage their risk of predation (Evans 2004; Whittingham & Evans 2004).

A lack of mature woodland in many places has resulted in reduced availability of cavities for hole-nesting birds (and other animals) which, in some cases, has necessitated the use of nest boxes. Pine martens will predate natural nests of medium sized hole-nesting birds such as Tengmalm's owl, *Aegolius funereus* (Sonerud 1985) and black woodpecker *Dryocopus martius* (Nilsson, Johnsson & Tjernberg 1991), but they are unable to access natural nest sites of small, hole-nesting passerines. This is not the case with nest boxes, however, which are also usually placed at relatively high densities and are distinctive in appearance, increasing their detectability. Predators remember the location of nest boxes where they have found food, and predation by pine martens on great tit *Parus major* and blue tit nest *Parus caeruleus* boxes has been shown to significantly increase with the length of time boxes have been in place (Sorace, Petrassi & Consiglio 2004). There are, however, practical measures that can be put in place to militate against this, which include placing nest boxes on less accessible branches or poles, fitting guards or making boxes from predator-proof materials (Summers & Taylor 2018).

Pied flycatcher *Ficedula hypoleuca* is one of the Amber List species present in both the Dartmoor and Exmoor PRRs. Natural cavities where this species would normally nest are usually too small for a pine marten to access. However, PiedFly.net, which covers 48 participating nest box schemes, mainly aimed at pied flycatchers in the region, should be consulted. These boxes might need to be modified to prevent martens from accessing them. The same is true for the hazel dormouse *Muscardinus avellanarius*. This species is unlikely to be predated by pine martens in natural nest sites or while active. However, dormice could be vulnerable to marten predation in a nest box, especially on cooler days when they go into torpor. Devon and Somerset are both counties with important dormouse populations and a number of monitored nest box schemes (Figure 11). Discussions should be held with stakeholders at these sites to inform them of the risk of predation by pine martens and to provide mitigation advice. Depending on the design used, some of these nest boxes may need to be slightly modified to prevent pine martens from being able to open them.

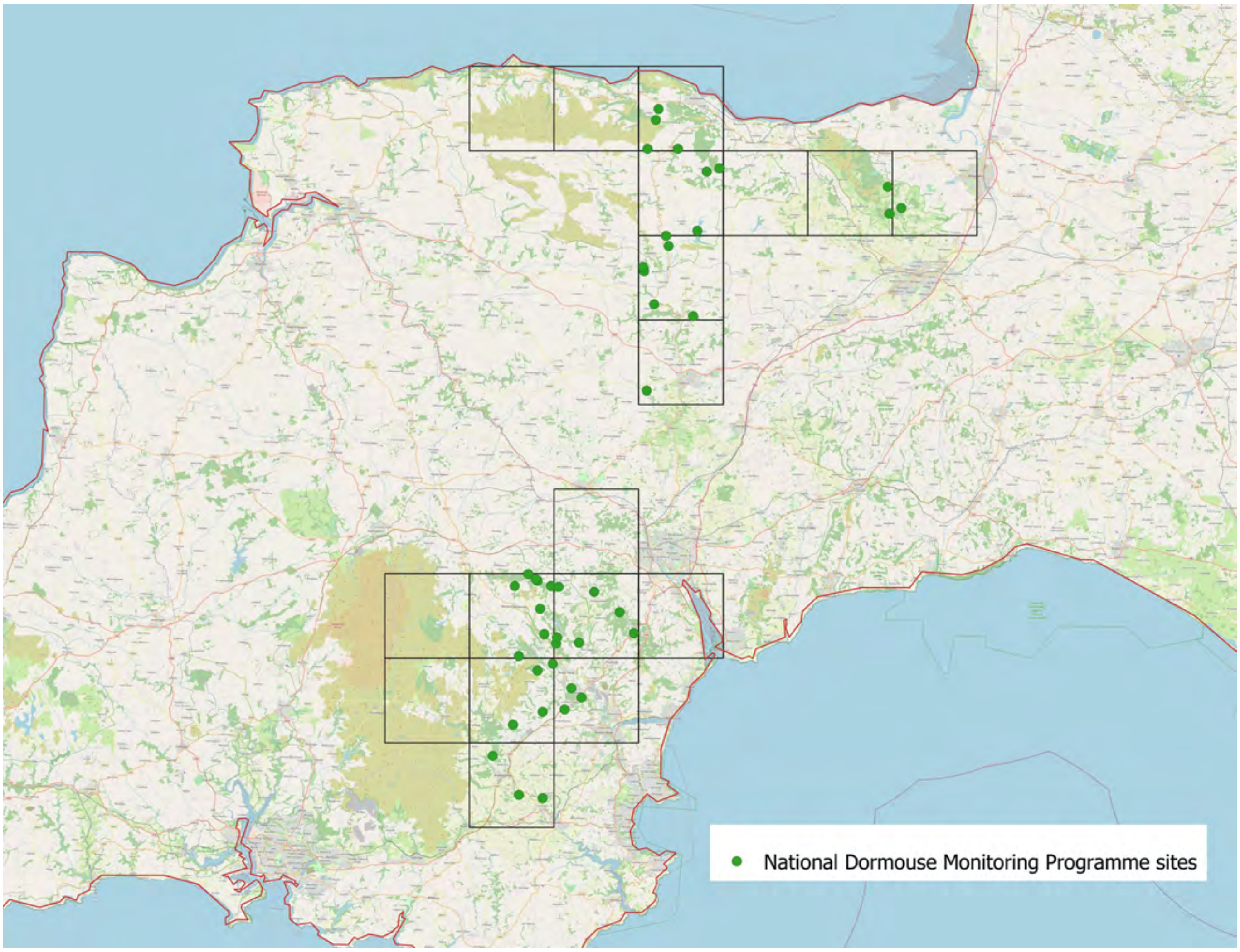

Figure 11 Important dormouse sites within the Two Moors PRRs.
Map produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0. Dormouse data from People's Trust for Endangered Species' National Dormouse Monitoring Programme, 2020.

In addition to species of conservation concern, species of economic importance must also be considered. Game shooting is an important part of the local and national economy and supports around 10,000 jobs in southwest England alone (PACEC 2014). There are a number of commercial shoots within the Two Moors project area (Figure 12) and these will be important stakeholders who should be engaged with from the outset.

Measures can also be taken to protect game species from pine marten predation. An extensive study of pine marten diet in Scotland found that the number of pheasants *Phasianus colchicus* taken by pine martens (2.9/km^2) represented less than 1% of the birds released (Halliwell 1997). This is a small proportion in comparison to other predators, but this relates to free-flying birds. Mammalian predators can cause considerable damage if they get into a pheasant release pen. However, it has been shown that pens can be protected against pine martens and other predators with slight adjustments (for details see https://pinemarten.ie/subject/gun-clubs/ and Balharry (1998)). The main focus here is primarily birds, a taxon for which reliable data were available from the BTO's national survey of breeding birds. However, other taxa must also be considered.

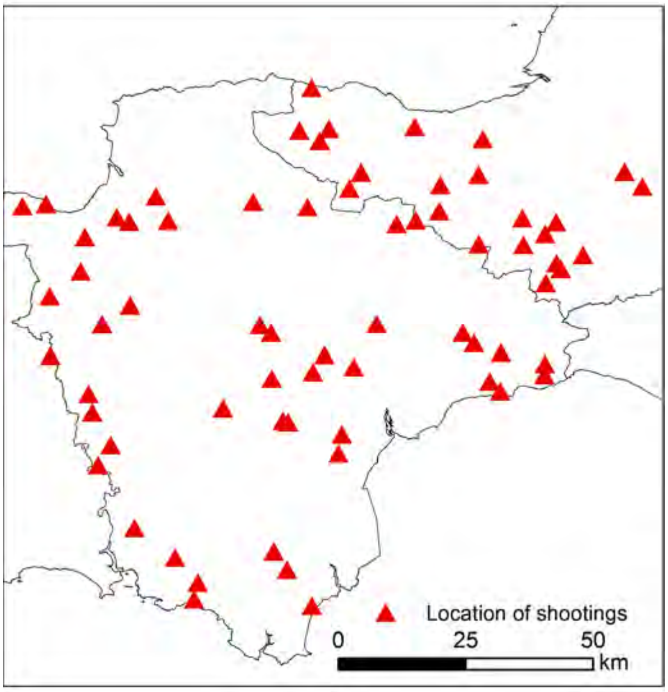

Figure 12 Locations of commercial shoots Devon and Somerset.
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Some bat species may be at risk from over-predation by pine martens under particular circumstances. Many of the woodland bats select roost cavities with entrances smaller than the width of a marten's head (Ruczyński & Bogdanowicz 2005) and previous dietary analysis suggested that pine martens very rarely eat bats (Zalewski, Jedrzejewski & Jedrzejewska 1995). However, bats have been found in the diet of stone martens *Martes foina* in Romania (Romanowski & Lesinski 1991) and Hungary (Lanszki, Sardi & Széles 2009), and in the underground tunnels of the Nietoperek bat reserve in Poland there are examples of stone martens preying almost exclusively (80% of food biomass) on bats (Urbanczyk 1981; Lesinski & Romanowski 1988). Recently it has also been found that some individual pine martens repeatedly visit these tunnels (Power 2015), and there are examples in the literature of martens frequenting places that they will find bats, such as the Marl pits in Holland (Bekker 1988). It seems that, while the concentration of bats in colonies reduces the chance of martens finding them, once a colony has been discovered it provides a readily available food supply. Therefore, it is important that any significant and accessible colonies of rare bats in and around PRRs in the Two Moors Project area should be properly risk assessed and appropriate mitigation put in place if considered necessary. A number of protected sites (SSSIs, SACs) in Devon and Somerset have one or more bat species listed as designated features. A Habitats Regulations Assessment (HRA) will need to be undertaken by the appropriate competent authority to consider in detail whether proposed pine marten reintroductions are likely to have significant effects on any site designated for its nature conservation interest and included in The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 (shown in Figure 13).

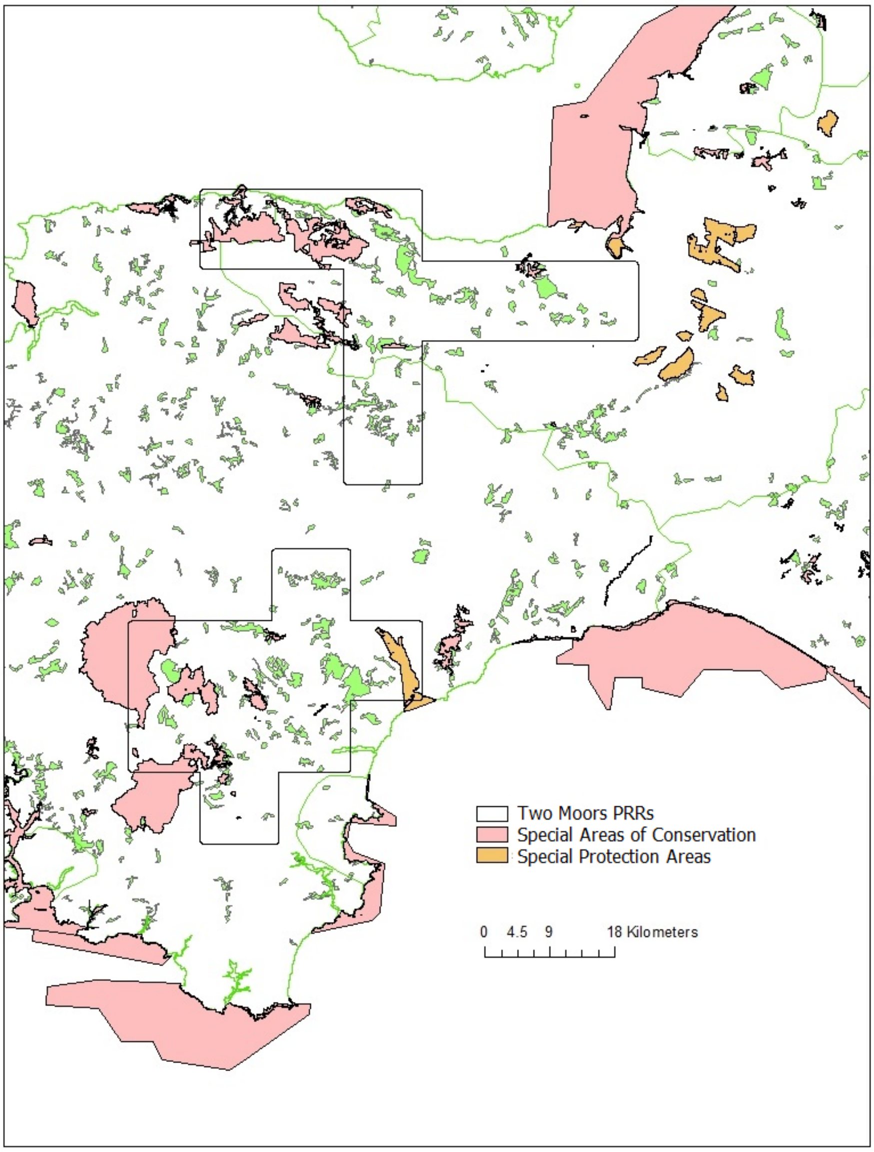

Figure 13 Special Areas of Conservation and Special Protection Areas in relation to Potential Reintroduction Regions (PRRs) for pine martens in the Two Moors Project area in Somerset and Devon.
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Across its range, including in Scotland and elsewhere in Europe, the pine marten coexists with many potentially vulnerable rare species. Pine martens are territorial, have large home ranges and live at low population densities, so their impacts on other species are likely to be lower than more common predators such as stoats *Mustela erminea* and foxes *Vulpes vulpes*. While it is unlikely that recovering pine marten populations would negatively impact other native species, it is important to evaluate specific potential risks in these areas in more detail, should a reintroduction go ahead. The species considered here were only those present within potential release areas, however, it is important to also evaluate the likely impacts in future, should translocations go ahead, and populations subsequently increase and expand.

The primary motivation for the interest in pine marten reintroductions expressed by many individuals and organisations is the expectation that they will provide a biological control for grey squirrels. There is evidence from Ireland and Scotland to suggest that, at relatively high densities, pine martens may have a negative effect on the occupancy of grey squirrels (Sheehy & Lawton 2014; Sheehy *et al*. 2018; Flaherty & Lawton 2019; Twining, Montgomery & Tosh 2020), but it is not certain that grey squirrel numbers will be reduced to extinction where pine martens occur.

Furthermore, even if this were the case, grey squirrels are still likely to persist in urban and other habitats that are avoided by, or unsuitable for, pine martens (Twining, Montgomery & Tosh 2020). Studies show that the interactions between martens and squirrels are clearly complex and influenced by a number of different factors, such as the abundance and types of alternative prey/food sources, habitat type and the densities of both martens and squirrels. More research is needed before we understand how or if pine martens might have a similar effect on grey squirrels in other areas, as has been observed in parts of Ireland and Scotland. Meanwhile, pine martens should not be regarded as a panacea for the problems caused by the grey squirrel in Britain. It is therefore recommended that expectations are managed in this respect when discussing potential pine marten reintroductions, and that any communications on this subject are updated to reflect emerging scientific evidence.

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4 Community and stakeholder engagement

Introduction

Successful reintroductions must consider the biological and social factors in the context of the species, habitats and landscapes where they are to take place. Local support and stakeholder participation in the decision process is vital for the long-term establishment, particularly of a carnivore reintroduction. Both the IUCN Guidelines (IUCN 2013) and The Scottish Code for Conservation Translocations (2014) emphasise the importance of social and cultural considerations in species restoration. Identification of groups and individuals that may be affected by potential reintroductions is a vital element in ensuring reintroduction success. These groups should be considered for inclusion in the planning process, including addressing any pre-reintroduction concerns and continuing dialogue about subsequent post-reintroduction issues or conflicts that may arise (IUCN 2014).

The original proposal was for VWT to lead on a social feasibility assessment, working closely with local staff from the partnership. However, plans to undertake initial engagement face-to-face with local communities and stakeholders in 2020 were not possible, due to COVID-19 and associated restrictions. An altered approach was taken, whereby VWT ran online training workshops for relevant staff of the partner organisations on key aspects of community and stakeholder engagement and consultation, based on VWT's experience gained during the Pine Marten Recovery Project and the successful translocations of pine martens to Wales. In this way, key personnel from the partnership will be in a position to commence engagement on the ground as soon as it is possible to do so.

Methods

During winter 2020/21, five workshops were run, cumulatively attended by 92 people from organisations within the partnership and some relevant external organisations and individuals. These workshops comprised an overview of the Two Moors pine marten partnership; the scope and content of the feasibility study conducted to date; an introduction to the status, habitat requirements and diet of pine martens; and a comprehensive outline of community and stakeholder engagement with relation to carnivore reintroductions. This covered the background and rationale for social feasibility and community and stakeholder engagement within reintroductions, the social challenges associated with reintroductions, perceptions of pine marten translocations to Wales as learnt from VWT's Pine Marten Recovery Project, and methods for identifying and consulting with local communities and stakeholders. The presentations were followed by a Q&A and discussion session.

Results

The content and focus of the discussion varied between the workshops, but the common themes and discussion points centred on:

- locality of the potential release areas;
- potential impact of pine martens on potentially vulnerable prey species (Red and Amber List birds, bats, dormice) and options for mitigation;
- potential impact of pine martens on the game bird rearing and shooting industry and options for mitigation;
- the likely movement and behaviour of pine martens post-release (eg, dispersal distances);
- pine martens and forestry/woodland management;
- the process of effectively selecting and targeting stakeholders for consultation;
- how a reintroduction may link in with other initiatives or schemes (eg, the new Environmental Land Management scheme, local initiatives within the national parks).

Discussion

Planning activities should be designed to develop trust and understanding with local communities, minimise potential conflicts and integrate stakeholders into the process from the outset. Information on the process should be shared with groups as planning proceeds. Project updates should be consistently provided, especially during milestone activities, to stakeholders and other interested groups. Dissemination of information through project partners via websites, social networks and other media outlets should be designed to be accessible and reach target audiences effectively.

VWT will be providing the Two Moors partnership with the tools to deliver community and stakeholder engagement and consultation as part of the social feasibility for the project. This will comprise:

- a resource pack for engagement (leaflets, posters, presentations);
- a comprehensive list of FAQs;
- generic pine marten articles (for local and national media);
- a draft Communications and Stakeholder Engagement Strategy and Action Plan;
- bespoke online engagement workshops, including a recording of the 2.5 hr workshop.

The next step for the partnership should comprise focused engagement and consultation with relevant stakeholders and local communities in the potential release areas, as per the recommendations in the Communications and Stakeholder Engagement Strategy and Action Plan to gauge the level of local support for a pine marten reintroduction and address any concerns.

5 Conclusions and recommendations

The preliminary feasibility assessment presented here suggests that a landscape-scale pine marten reintroduction project across Devon and Somerset warrants further investigation. The most conservative habitat suitability model, based on GIS data, shows that the large area of woodlands parallel to the northern coast of Somerset is the most contiguous region of highly suitable habitat for pine martens within the Two Moors project area. There is also a large swathe of good habitat running south from Bideford to Holsworth and then Okehampton. This is made up of a series of 'stepping stone' woodlands that link the northern project area to that around Dartmoor in the south. Whilst these woodlands contribute to the overall habitat suitability of this area and are highly likely to be utilised by pine martens once established, none are likely to be suitable release sites, due to their individual size and conformation. However, this is subject to verification by field survey.

In the north of the project area, in and around Exmoor, the large woodlands to the northwest and southwest of Dunster are probably the most suitable for releases. The size and connectivity of these forest blocks would minimise risks to the released animals while finding and establishing territories. It is suggested that community engagement should start initially by radiating out from these woodland edges. There are a lot of farms and houses in and around the towns and villages of Dunster, Cowbridge, Timberscombe, Wootton Courtenay and Tivington. The main towns could be incorporated later and would include Minehead and Porlock. For the southern project area, in and around Dartmoor, the steep valley woodlands to the north and south of Moretonhampstead might be suitable release sites. This would avoid having a release site with the A38 going through the middle of it. So, it is recommended that community engagement is targeted in this region down as far as Bovey Tracey.

One potential issue with the Two Moors project area is that it is effectively bisected by the A30 running east to west between the two national parks. If martens were released in the area on the southeastern side of Dartmoor, there is currently a break in 'current' (connectivity) predicted by the Circuitscape models between Chagford going north west to Okehampton. From there, the habitat is suitable and well-connected going north almost up as far as Barnstaple. However, there appears to be a gap in connectivity between Great Torrington and Umberleigh, despite some small woodlands between the two, which should be investigated further. Potential for improving these corridors could be explored.

Population viability analyses suggest that between 30 to 40 pine martens need to be released in an area to maximise the viability of the founder population (Bright & Halliwell 1999, MacPherson 2014, unpubl.data). Where there are still suitable donor populations in the wild, it is recommended that wild caught animals are used for reintroductions (Griffiths & Pavajeau 2008). These generally show higher survival and better adaptation to new environments than captive bred animals, and this is especially true for carnivores (Jule, Leaver & Lea 2008). Donor populations should show characteristics based on genetic provenance, morphology, physiology and behaviour that are appropriate to the reintroduction sites. A published study comparing the haplotype composition of historical and current pine marten populations in England, Scotland and Wales found no differences between the main haplotype of contemporary (post-1950) populations across the UK (Jordan et al. 2012).

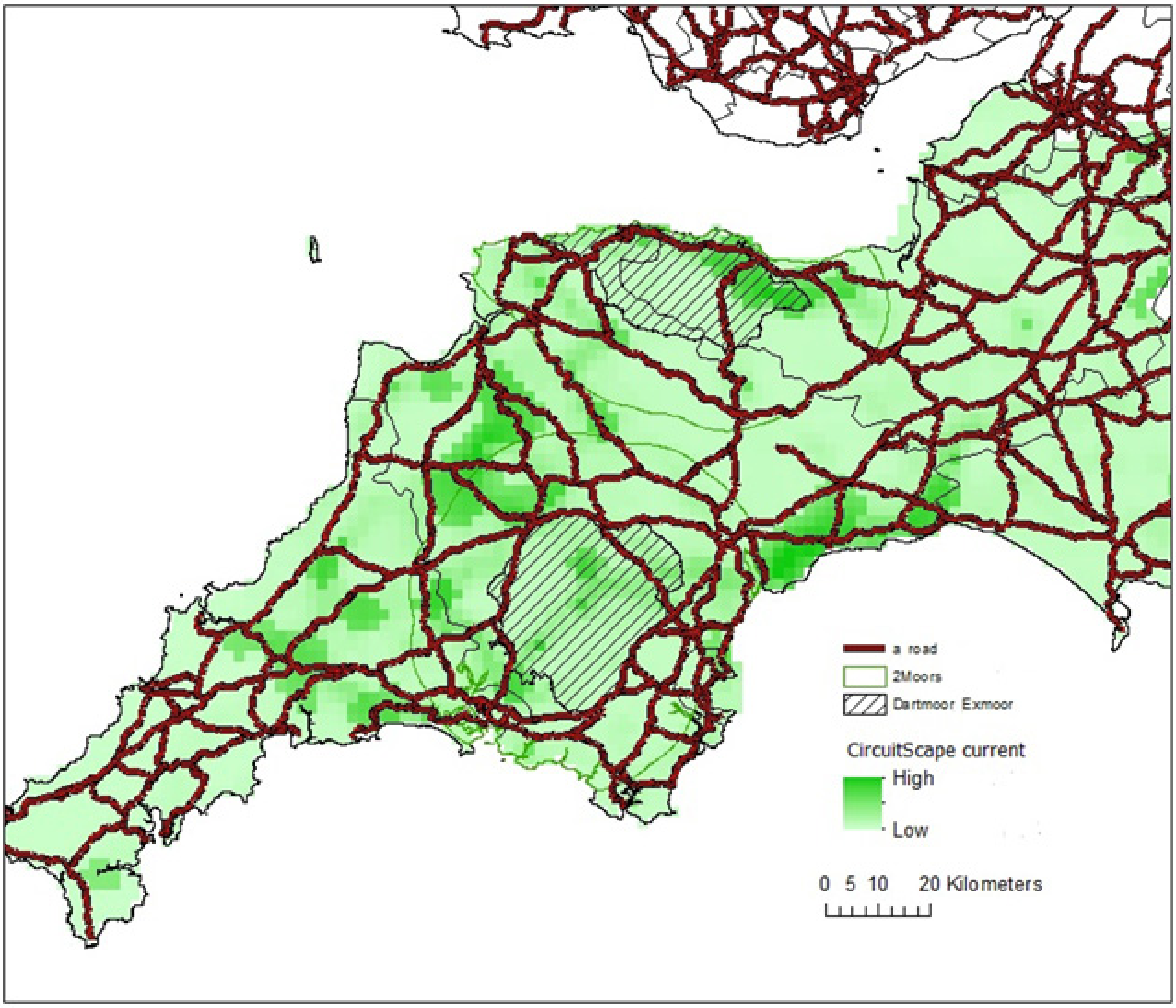

Figure 14 Landscape permeability (current) and major roads within and between the Two Moors project areas.
Maps produced using OS Open Data. Contains public sector information licensed under the Open Government Licence v2.0.

Therefore, the increasing and expanding population of pine martens in Scotland is currently the most suitable source of animals for translocations elsewhere in mainland Britain. However, any harvesting must be carefully managed to avoid negative impacts on recovering Scottish populations. It is important to conserve the recovering pine marten population in Scotland, and so reintroductions should only be to the most optimal regions in a way that has the minimum risk to donor populations and maximises the probability of reintroduced populations establishing, spreading and ultimately linking up.

There is currently increasing interest in pine marten reintroductions across Britain, but proposed projects are often locally planned and motivated without knowledge of other, similar projects or consideration of how they fit within the wider context of pine marten conservation. With this in mind, Vincent Wildlife Trust, in partnership with NatureScot and Natural England, have produced a long-term, strategic recovery plan for pine martens in Britain (MacPherson & Wright 2021). This sets out a structured decision-making approach which balances conservation of the recovering pine marten population in Scotland, with growing interest in the use of translocations as a means to restore the species to parts of its former range elsewhere in Britain. When this framework was applied to a number of regions in Britain to assess their potential for pine marten recovery or restoration, the results suggested that the southwest of England should be prioritised for further investigation as a potential reintroduction region.

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