ADAPTING TO CLIMATE HEATING

How rewilding can help save Britain’s wildlife from extinction during the climate emergency

REWILDING BRITAIN

AN INTERCONNECTED NETWORK OF CORE REWILDING AREAS AND WILDLIFE FRIENDLY MOSAIC LANDSCAPES IS URGENTLY REQUIRED ACROSS BRITAIN TO ENABLE SPECIES AND COMMUNITIES TO ADAPT AND ADJUST THEIR RANGES IN THE FACE OF THE ACCELERATING CLIMATE EMERGENCY.

SUMMARY

Britain should be teeming with wildlife. Instead many of our wildlife populations – from songbirds to insects and plankton – are collapsing. Some individual populations are recovering but many once-common species are being driven to apparently terminal decline. This is reflected across the world as human pressures – for example, intensive agriculture and over-exploiting of natural resources – create what is now termed the Sixth Mass Extinction[1]. Climate heating comes on top of these pressures – reducing, transforming and eliminating great swathes of the living world.

Research suggests that rising temperatures through climate heating are causing climate zones across the northern hemisphere to move northwards, and upwards in elevation, at an unprecedented rate. We estimate that climate zones in Britain are moving northwards at up to 5km a year. This is hundreds of times faster than our islands experienced during the natural climate warming at the end of the last ice age.

For Britain's wildlife this could be catastrophic. The ability of plant and animal species to survive such a rapid shift will depend partly on their ability to disperse and shift their ranges to new areas that become climatically hospitable. If a given species is unable to shift across the land or sea at roughly the same rate as the climate zone upon which it depends, its population will likely decline and be at increased risk of extinction.

Our wildlife is already severely depleted and in no fit state to withstand the shock of current and future predicted climate heating. The network of protected areas and nature reserves across Britain is too small and fragmented to offer sufficient habitat for most migrating species in future. Nature reserves – currently established and maintained for the benefit of certain species and assemblages – may find that they are no longer in the appropriate climate zones for most of the species they are supposed to protect.

Additionally, the intensification of other land and marine uses – including farming, forestry and fishing – threatens to further undermine the connectivity which is needed to facilitate the range shifts of species over long distances in decades to come. Climate heating is accelerating each year. Urgent, concerted action across land and sea is required if we are to have much hope of halting species and habitat losses, let alone reversing them. We argue that this concerted action must include rewilding. We have already demonstrated that rewilding provides a cost-effective solution for mitigating climate heating with its ability to draw down millions of tonnes of carbon from the atmosphere[2]. By supporting the movement and re-establishment of ecological communities, rewilding can also play a major role in climate adaptation.

The evidence in this report suggests that enhancing the scale, quality and connectedness of our native habitats would enable more species and communities to adapt and adjust their ranges as climate zones shift. This could save a substantial fraction – perhaps up to one fifth[3] - of Britain's species from climate-driven habitat loss, species decline or even extinction.

Now is the time to urgently accelerate nature's recovery across at least 30% of Britain's land and seas by 2030 to match the scale of the threats from accelerating climate heating and species extinction.

CLIMATE ZONES IN BRITAIN ARE MOVING NORTHWARDS AT AN ESTIMATED 5KM A YEAR

To achieve this we must see the establishment of much expanded rewilding areas where natural processes are allowed to govern and shape the land and seascapes. These should be embedded within a wider nature-friendly mosaic of land and marine uses that enhance nature's restoration. The recovery of nature at scale on its own terms will help build resilience to the dramatic changes ahead. We see two complementary priorities:

1. CREATION OF CORE REWILDING AREAS

First, the creation of core rewilding areas across at least 5% of Britain to enhance and urgently expand the scale and ecological integrity of our marine and terrestrial protected areas and reserves. These areas should focus on restoring and reinstating as wide a range of natural processes, habitats and related species as possible.

2. ESTABLISHMENT OF 'NATURAL DISPERSAL CORRIDORS'

Second, the establishment of 'natural dispersal corridors' across at least 25% of Britain that embed core rewilding areas within broader mosaics of nature-friendly land and marine uses which enhance nature's recovery. These corridors should substantially expand habitat quality and connectivity in a way that allows species to disperse and migrate as climate zones move.

By configuring core and mosaic areas as interconnected land and seascapes, we can allow species to more easily shift in response to climatic changes. Wild plants and animals will be able to move across ecologically permeable landscapes and re-assemble into novel food webs as climate zones move north and to higher elevations. In this report, we summarise some of the evidence that supports this proposition.

CREATE CORE REWILDING AREAS & NATURAL DISPERSAL CORRIDORS

THE UK IS RANKED **189TH** OUT OF 218 COUNTRIES FOR **BIODIVERISTY INTACTNESS**

INTRODUCTION

Climate zones are the sum of an area's temperature, humidity, amount and type of precipitation, and seasons. They help to determine the distribution of species and the habitats they form.

The Earth is a dynamic system and climate zones have shifted across latitudes and altitudes throughout the history of life. But anthropogenic climate heating is causing much more rapid disruption and triggering severe climatic changes.

Research by the IPCC and others suggests climate change is causing climate zones across the northern hemisphere to move northwards, and upwards in elevation, at an unprecedented rate. Based on this research we estimate that across Britain climate zones are moving northwards at up to 5km a year. This rate is hundreds of times faster than species recolonisation after the last ice age. The ability of plant and animal species to survive such a rapid shift will depend partly on their ability to disperse to areas that are climatically hospitable.

Movement of wildlife is currently hampered by the depleted state of nature in the UK, which is ranked 189th out of 218 countries for biodiversity intactness[4]. Protected areas for nature exist largely in isolated pockets. In many cases they don't contain the structural, functional or compositional components, or the complete food webs and natural disturbance regimes, which interact to determine biodiversity. Species-based conservation approaches, which aim to maintain protected areas at a certain snapshot in time (i.e. before human-driven climate change and as samples of now redundant farm systems), will often no longer be viable as shifting climate zones and further agricultural change pull species away from their current ranges and deplete regional wildlife populations.

Climate heating is now increasingly recognised as the greatest future threat to our biodiversity. We have already demonstrated that rewilding could provide a cost-effective solution for the mitigation of climate heating with its ability to draw down millions of tonnes of carbon from the atmosphere[5]. In this report we show that rewilding can also play a major role in climate adaptation by supporting the dynamic movement and re-establishment of ecological communities.

IMPACTS OF CLIMATE HEATING AND BIODIVERSITY

One key determinant of the impacts of climate heating on biodiversity is 'climate velocity'. This term has been defined as the speed at which species will need to migrate in order to stay in the same enveloped climatic condition (climate zone)[6]. Climate velocities vary widely because different parts of the world are heating up at different rates – the poles and higher latitudes are warming fastest, for example.

Flatter areas have higher climate velocities than areas with highlands because there is a much faster natural temperature drop with elevation than latitude. So species would only have to move 150 metres upwards to find a 1°C drop in temperature but 150 kilometres or more in northward latitude to find that same temperature difference.

Predicted climate velocities vary according to emissions scenarios and associated rates of planetary heating. Higher emissions scenarios, with more rapid and intense warming, will of course have faster climate velocities. The IPCC's 2014 Fifth Assessment Report (AR5) projected a future global average climate velocity for terrestrial flat areas of about 7 km/year for a high-emissions scenario[7]. For a more moderate emissions scenario with slower warming, climate velocity peaks at about 4 km/year in 2050[8].

While there are no hard and fast figures for the UK, studies from elsewhere for flat, northern hemisphere areas support the IPCC figures. For the purposes of this report, climate velocity in the UK is taken to be 5km/year under a moderate emission scenario, which we consider reasonable for a high latitude, largely flat area. This number is likely conservative given that future warming is projected to be more rapid than experienced to date. The marine environment is already seeing higher climate velocities, with estimates for the seas around the UK above 10 km per year[9].

What is clear is that the climate velocities predicted for the rest of this century are historically unprecedented. They are many hundreds of times faster than the average rate of species re-colonisation after the last ice age[10]. And therefore they risk far outstripping the evolved natural dispersal capacities of many species.

CLIMATE VELOCITY:

THE SPEED AT WHICH SPECIES WILL NEED TO MIGRATE IN ORDER TO STAY IN THE SAME CLIMATE ZONE AS THE WORLD HEATS UP.

SPECIES DISPERSAL ABILITY

The ability of plant and animal species to survive such a rapid shift will depend partly on their ability to disperse and shift their ranges to areas that are climatically hospitable. If a given species is unable to shift across the landscape at approximately the same rate as the climate zone upon which it depends, its population will likely decline and its extinction risk increase.

Species vary in their capacity to disperse. Trees, for example, can't just uproot themselves and move, but must grow to maturity and set seed. For some, this can take up to thirty years. Even then, the dispersal distance for the seeds of most temperate tree species only extends to a few tens of metres on average from the parent[11].

DNA studies of American beech and red maple suggest that these trees were able to re-colonise post-glacial landscapes (from small isolated refugia quite close to the edges of the ice sheets) at about 100m per year after the last ice age[12], a far shorter distance than the 5000m per year climate velocity predicted for the UK.

A study in western North America found that forest tree species populations 'already lag behind their optimal climate niche by approximately 130 km in latitude, or 60 m in elevation'[13]. Meanwhile lowland forests in France would have needed to move 35 km to keep up with warming since the 1980s, but there has so far been no sign of such a shift[14].

Trees are generally long-lived plants. Plants and animals with shorter lifecycles could, theoretically at least, mostly move more quickly. According to the IPCC, carnivorous mammals can disperse at 6km/year (median estimate), while split-hoofed mammals (like deer) can shift their ranges at 9 km/year. Rodents are less mobile, however, generally shifting at less than 1km/year. Freshwater molluscs meanwhile have median dispersal rates of about 3km/year[15]. Other studies have found that butterflies in North America and the UK have shifted at 2-4 km per year due to ongoing climate change over recent decades[16].

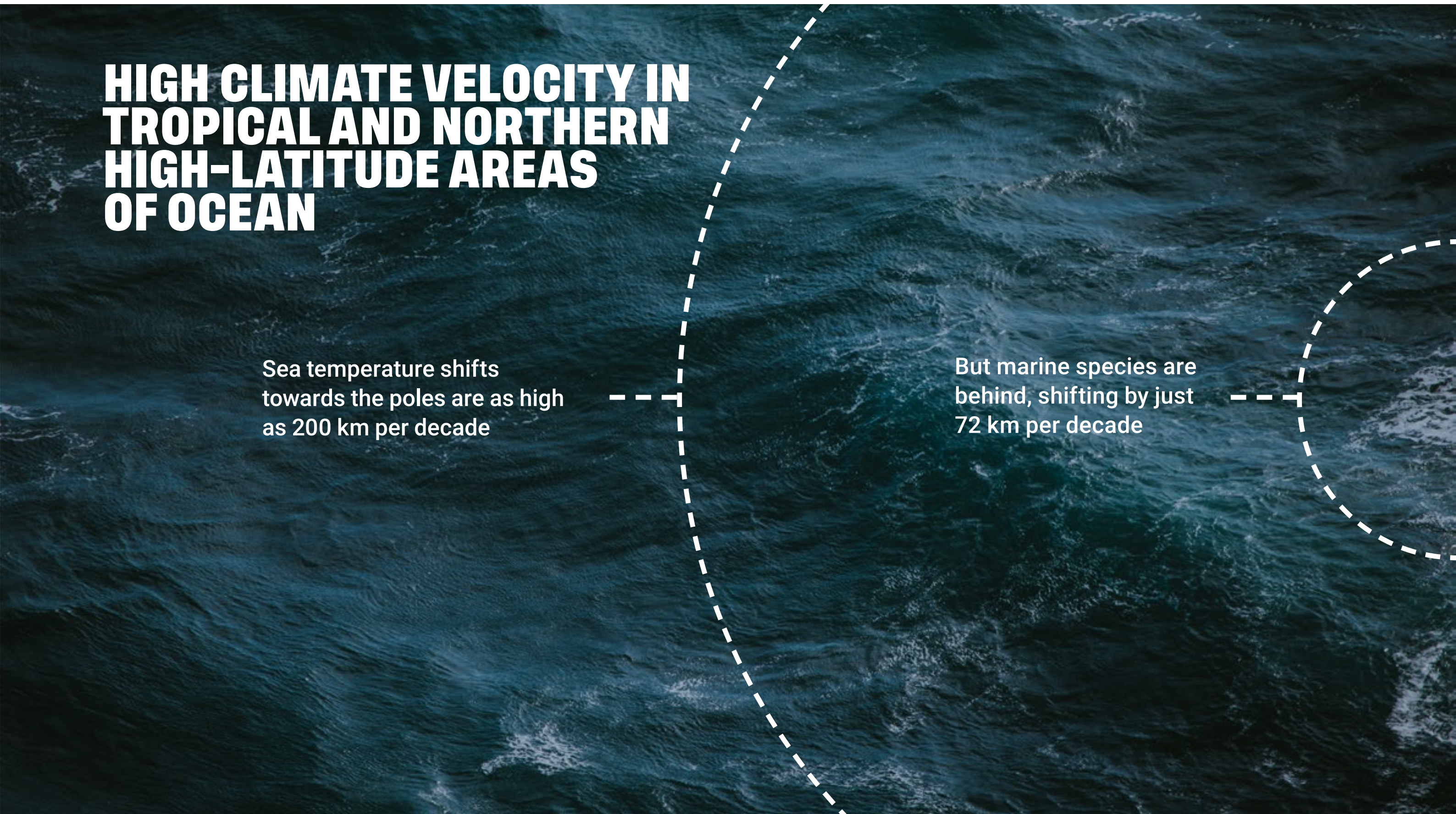
However, even these dispersal rates may not be fast enough. In Canada, a study based on observations of 81 species of butterfly found that 'these pollinators have been unable to extend their ranges as fast as required to keep pace with climate change'[17]. As for fish, the IPCC AR5 report states that while freshwater fish species are moving upstream and towards higher elevations, they are 'not keeping pace with the rate of warming in streams and rivers'[18]. A study of birds in France found a 91 km northward shift in community composition over two decades, but this was still insufficient to keep track with climate heating[19].

In the UK, a study of 21 different animal groups over the past four decades found that many – though not all – were moving north. Birds, butterflies, large moths and dragonflies/damselflies were shifting the northward edges of their ranges by about 20 km per decade[20]. These movements are less, however, than the shift in climate space. Many species are failing to keep pace with climatic changes.

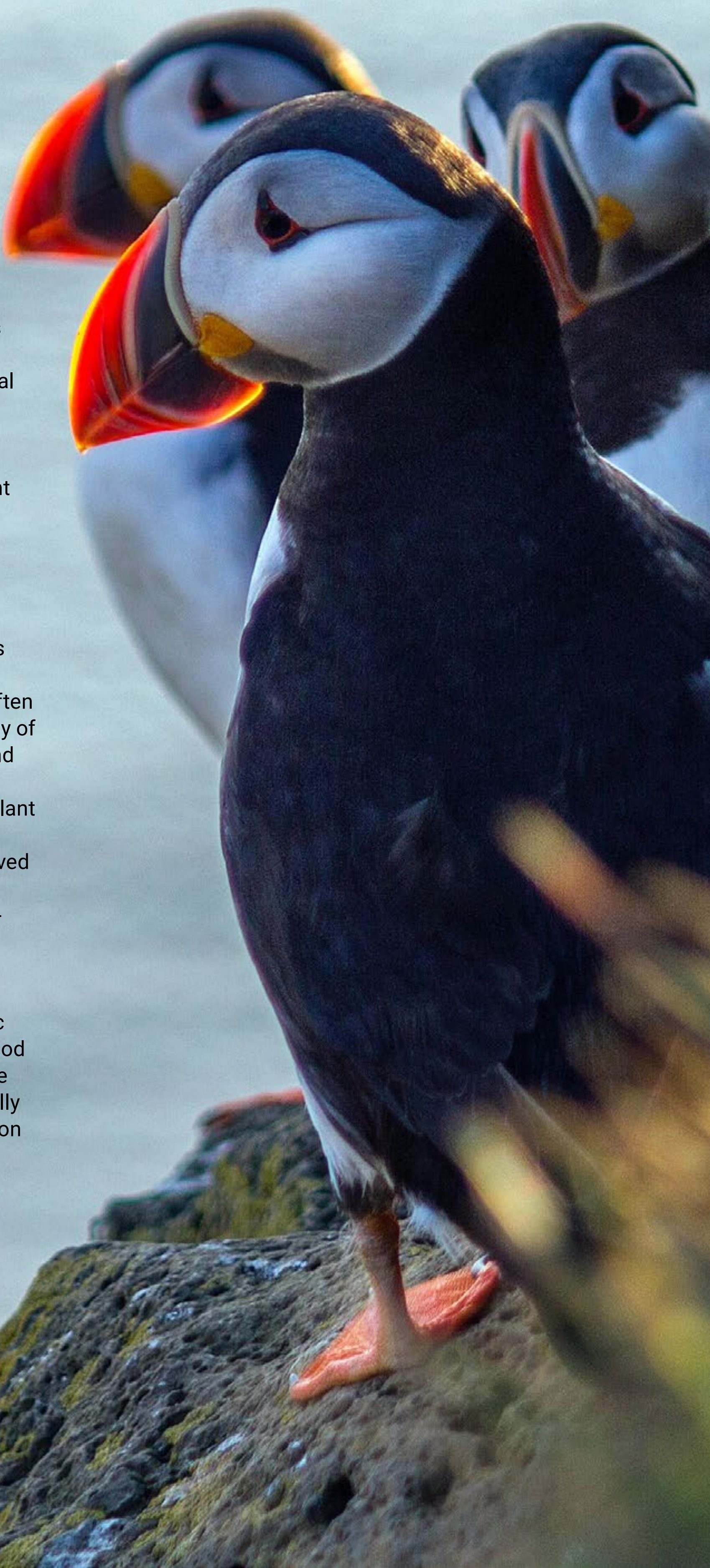
Some species are losing ground at the southern, warmer edges of their ranges without being able to gain ground by moving north fast enough. A cross-continental study on North American and European bumblebees found that 300 km had been lost from the southern portions of their ranges, while no northward shift was observed despite regional warming of 2.5 degrees C[21]. These observations were independent of confounding factors such as land-use change and pesticide use, and mean that the bees were seeing an overall contraction in their range and available habitat.

In the ocean there are fewer barriers to movement, but studies show northward movement of climate zones is still an issue. Like the land surface, the oceans are heating unevenly. In tropical and northern high-latitude areas, the velocity of sea surface temperature isotherm shifts can be as high as 200 km per decade towards the poles[22]. But in its fifth assessment report, the IPCC found that marine species have only shifted in a poleward direction by 72 km per decade[23]. This is similar to the rate found by the most recent meta-assessment, published in July 2020, which found marine species were moving towards the poles at a rate of about 6 km per year[24]. This was almost six times faster than the range shifts found in terrestrial species, suggesting that species are much better able to track warming in the oceans than land.

One marine area with a high climate velocity is the North Sea. A recent study of North Sea benthic invertebrates (those that live on the bottom of a water body) reported that their ranges would need to shift by 8 km in latitude per year to keep up with climate change, but populations are currently moving at a lesser rate of 4-7 km per year[25]. Meanwhile, the RSPB reports that warm-water species such as red mullet, sardines and anchovies, seahorses and squid are moving north at rates of up to 50 km per year[26].



DISPERSAL WITH DEPENDENT SPECIES



Many species are tightly dependent upon other species within their ecological community. Climate heating is increasingly altering the composition of these ecological communities, in combination with other environmental pressures such as high-intensity land use. Therefore, it is not just the ability of a given species to move that is important; the timing of movement with inter-dependent species needs to coincide. This means climate change is already altering the composition of ecological communities, with cascading effects that could lead to further species extinctions.

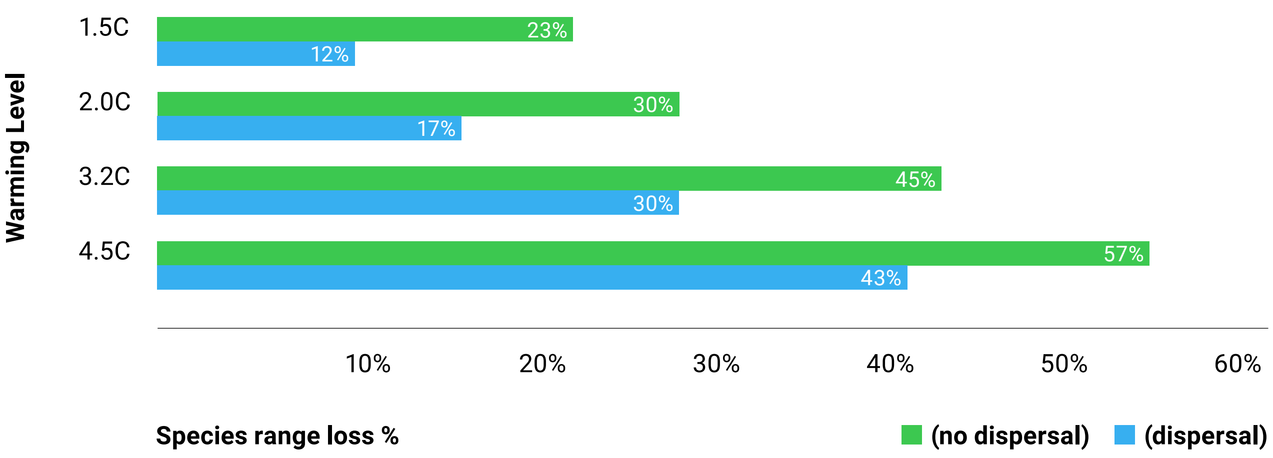
Migrating birds, for example, may find their arrival times mismatched with the peak availability of insect food sources like caterpillars. Migrant songbirds in the UK often time breeding such that broods coincide with availability of key prey. If such coincidences fail, breeding success and therefore population size could decline. Pollinators like wild bees increasingly find themselves mistimed with plant flowering, which may be matched to day length rather than temperature. In our seas, there has been an observed mismatch in timing between the onset of zooplankton blooms in the North Sea and breeding times of coastal-nesting marine seabirds and juvenile cod recruitment since the start of this millennium[27].

The failure of one species to breed can lead to a trophic cascade, which affects other species throughout the food web. In seas around the UK, rising temperatures and the resulting shifts in plankton populations have dramatically reduced the availability of sand eels, leading to starvation and reproductive failures among seabirds such as kittiwakes, Arctic terns, guillemots, puffins and shags further up the food chain[28].

IMPACTS OF SPECIES DISPERSAL ON BIODIVERSITY OUTCOMES

It is clear that, along with the pace of climate heating, the ability of species to disperse is one of the key determinants of the impacts that future climate projections will have on biodiversity. A number of studies have looked into the scale these impacts. A 2004 study estimated that under maximum rates of warming by 2050, 38-52% of species would be 'committed to extinction' under a no-dispersal scenario, as compared to 21-23% of species with unlimited dispersal[29].

Rachel Warren and colleagues recently revisited these general estimates, derived from species distribution modelling, using a somewhat different approach[30]. These authors provide a global assessment of the potential impacts of climate warming on the range sizes of more than 115,000 terrestrial species. The study specifically examines the impact of the Paris targets of 1.5 and 2 degrees, and the current pledges of world governments, which lead to a 3.2°C warming outcome, as well as an extreme warming scenario of 4.5°C. Warren et al then calculate a 'total integrated range loss' resulting from these different scenarios and assumptions (see Table below and Appendix 1 for full discussion).



THIS IMPLIES THAT INCREASING THE SCALE, QUALITY AND CONNECTEDNESS OF OUR NATIVE HABITATS COULD POTENTIALLY SAVE UP TO 20% OF THE UK'S BIODIVERSITY FROM HABITAT LOSS, DECLINE OR EXTINCTION.

A key conclusion from both studies is that there will be an enormous difference in most species' range size loss depending on whether or not they are able to disperse into new habitats as climate zones move. This implies that increasing the scale, quality and connectedness of our native habitats could save a substantial fraction – potentially up to one fifth – of the UK's biodiversity from climate-driven habitat loss, species decline or even extinction.

However, Warren and colleagues point out that currently, a no-dispersal scenario is arguably the most realistic projection given 'that the present-day landscape contains many barriers resulting from human modification of the landscape and associated habitat fragmentation'[31]. They add that 'barriers can include roads, urban areas and agricultural areas' as well as natural features like valleys, rivers and estuaries. Given that the UK is a highly human-modified environment, these constraints are particularly relevant.

RESILIENCE OF BRITAIN'S WILDLIFE TO CLIMATE HEATING

We can reach two important conclusions from our understanding of the interactions between biodiversity and climate heating. The first is that higher levels of climate heating will lead to inevitably worse outcomes for biodiversity. The second is that for each level of heating, facilitating maximum 'species dispersal' significantly decreases the expected loss of species and habitat. In other words, allowing species to shift their ranges alongside the movement of climate zones reduces the overall range loss under any global heating scenario.

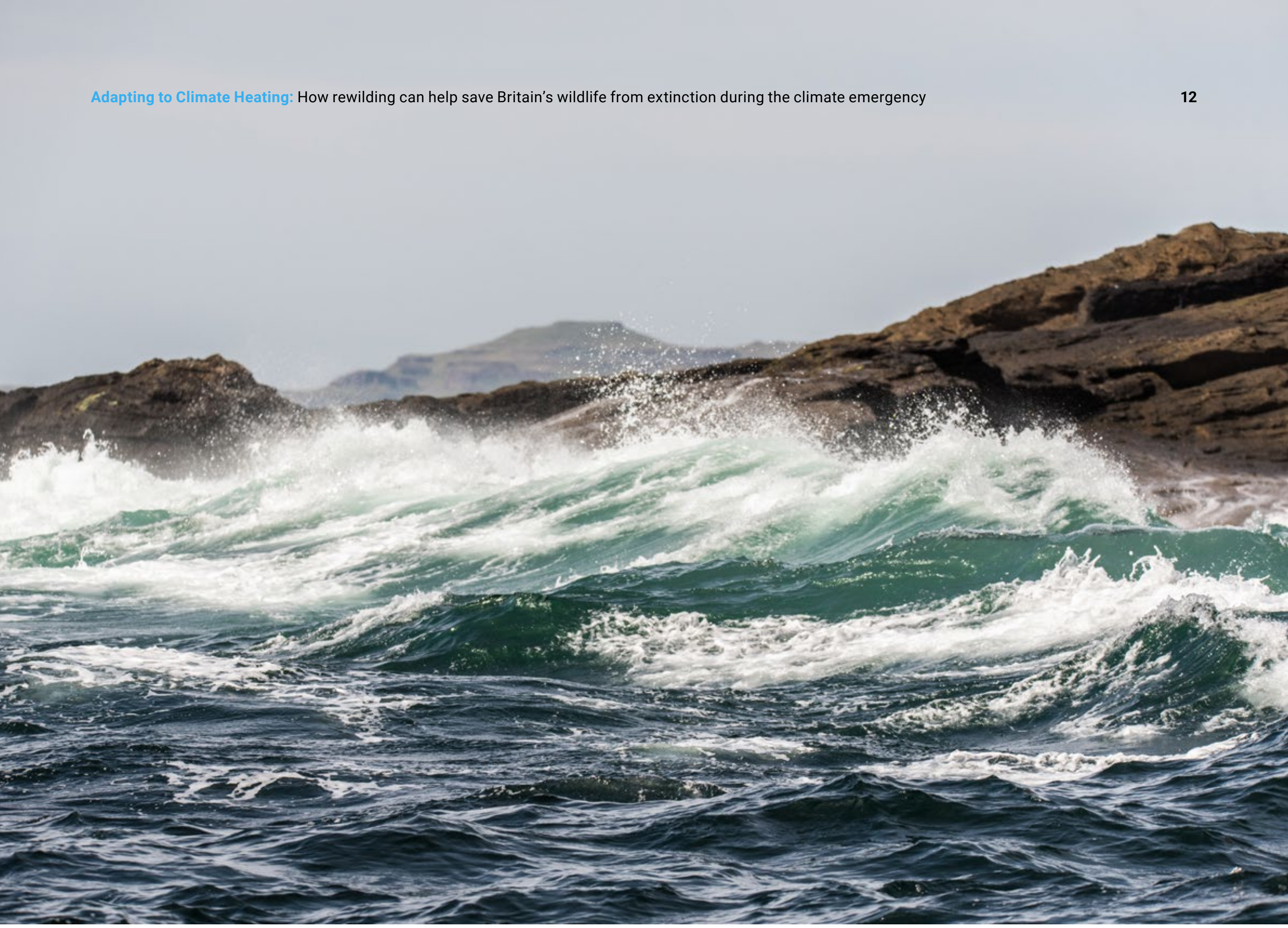
Therefore, while it is essential to urgently intensify efforts to reduce emissions and the resulting warming trajectories (i.e. climate mitigation), it is also vital to do whatever we can to try to facilitate species dispersal as the climate heats up (i.e. climate adaptation).

Our wildlife is already in a severely depleted state and in no fit state to withstand the shock of climate heating.

THE NETWORK OF PROTECTED AREAS AND NATURE RESERVES ACROSS BRITAIN IS TOO SMALL AND FRAGMENTED TO OFFER SUFFICIENT HABITAT FOR MOST MIGRATING SPECIES IN FUTURE.

Additionally, the intensification of other land and marine uses – including farming, forestry and bottom trawl fishing – provides little permeability or connectivity to facilitate the range shifts of species over long distances in decades to come.

A basic first step is to ensure existing wildlife sites are in good condition, with thriving wildlife populations able to withstand and adapt to changing conditions. Britain is largely failing in this regard. The state of many of our protected areas (PAs) is extremely poor, with many SSSIs affected by ploughing, pesticides, road-building, drainage, hunting, burning and so on. Meanwhile, our national parks lack the powers and funding necessary to protect biodiversity from exploitation by hunting, damage by visitors and degradation by agriculture. Many British national parks incorporate conventional farmland or intensively managed grouse shooting estates and are therefore indistinguishable from these land uses.



THE MARINE ENVIRONMENT IS SIMILARLY AFFLICTED. LESS THAN 5% OF UK SEAS ARE EFFECTIVELY PROTECTED BY LAW FROM SEABED TRAWLING, AND ONLY A MINISCULE 0.00003% OF THE SEAS ARE FULLY PROTECTED FROM ALL FISHING AND DUMPING[32].

But simply bringing protected wildlife sites into good condition will be insufficient. Rapid climate heating challenges our existing paradigm of static, site-based species and habitat conservation. Nature reserves – currently established and maintained for the benefit of certain species and assemblages – may no longer find themselves in the appropriate climate zones for some of the species they are supposed to protect.

In eastern England, bitterns – which have begun a fragile population recovery due to intensive conservation efforts by RSPB and others – are now threatened by sea-level rise, which could flood their reedbed habitats with saltwater[33]. We already saw this happening in the floods of 2007 when flash floods washed away numerous bittern nests[34]. Likewise Britain's biggest butterfly, the rare and beautiful swallowtail, also faces catastrophic habitat loss due to rising seas[35].

As well as sea level rise, ecological communities are at risk from other extreme weather patterns caused by climate change, such as fires, floods and droughts. Species with very low populations concentrated in a small geographical area are especially vulnerable to such extreme weather events. Ecosystems and the species within them are more likely to survive such extreme events if they are robust, diverse and have the ability to disperse if needed.

None of this means that protected areas have served their use and should be abandoned. Rather they will be even more crucial. There is substantial evidence that wilder protected areas, with higher ecological integrity, can serve as refugia and protect species from climate warming more effectively than neighbouring unprotected areas. For example, a study of Finnish protected areas found that cold-adapted birds were able to persist for longer inside these areas despite climate warming[36].

There is evidence that protected areas can act as stepping stones in facilitating range shifts of more mobile species. For example, according to a recent paper[37], the silver-spotted skipper butterfly has been shown to disproportionately colonise protected areas (PAs) across the South Downs in southern England as it moves its range north. The authors of the report suggest that:

'The 40-year track record of species responding to environmental change in PAs suggests that networks of PAs have been essential in biodiversity conservation and are likely to continue to fulfil this role in the future'. Protected areas have also acted as valuable 'landing pads' for range-shifting birds arriving in the British Isles from further south, including little egrets, common cranes, whooper swans and Cetti's warbler[38]. There is also evidence that in the face of climate heating multiscale networks of macro and micro-refugia which span broader climatic and elevational gradients are also more effective than single large protected areas[39].

Beyond protected areas and nature reserves it is also clear that increasing permeability and connectivity between sites facilitates the range shifts of species over long distances. Conservation groups have been highlighting this for many years. As the British Trust for Ornithology (BTO) writes, 'a much discussed principle of climate change adaptation is that of having increasingly connected landscapes, with networks of semi-natural habitats'[40]. The results of a study of 600 English bird and butterfly monitoring sites over three decades demonstrated clearly that intensive land use around the sites hampered the adaptation potential of species, with "large areas of intensively managed land limiting 'adaptive' community reorganization in response to climate change"[41].

As BTO co-authors write: "This provides a clear recommendation to land managers and conservation agencies – creating larger natural areas in strategic places will help species to cope with the changing climate." [42] This conclusion is supported by the latest meta-analysis of how species are tracking climate shifts, whose authors warn: "On land, habitat loss and fragmentation due to land use changes may impede the ability of terrestrial species to track shifting isotherms."[43]

Instead of abandoning current conservation sites we must, in fact, redouble our efforts to improve their ecological integrity as well as enhancing the connectivity between them. This will enhance biodiversity and also increase its ability to adapt to future climate events and damages, assisting species persistence and maintaining sufficient source populations to track their shifting climate zone through dispersal across regions.

REWILDING CAN HELP SAVE BRITAIN'S WILDLIFE

Rewilding is the large-scale restoration of ecosystems where nature can take care of itself. It seeks to reinstate natural processes and, where appropriate, missing species – allowing them to shape the landscape and the habitats within.

Rewilding encourages a balance between people and the rest of nature where each can thrive. It provides opportunities for communities to diversify and create nature-based economies; for living systems to provide the ecological functions on which we all depend; and for people to re-connect with wild nature.

We have already shown that rewilding can provide a cost-effective solution for the mitigation of climate heating with its ability to draw down millions of tonnes of carbon from the atmosphere [44]. With its ability to support the dynamic movement and re-establishment of ecological communities, rewilding can also play a major role in climate adaptation as our climate heats up.

Enhancing the scale, quality and connectedness of our native habitats would enable more species and ecological communities to adapt and adjust their ranges as climate zones shift. This could save a substantial fraction - perhaps up to one fifth [45] – of Britain's biodiversity from climate-driven habitat loss, species decline or even extinction.

As climate heating is accelerating each year, there is no time to lose if we are to have a hope of halting species and habitat losses let alone reversing them. A radical change is needed in the way we manage our land, sea and other natural assets if we are to meet our climate goals and allow wildlife to move and adapt as climate zones shift north at the same time as reversing biodiversity declines.

Given the sheer complexity of food webs and ecology generally, it will be impossible – as well as ecologically undesirable – for humans to attempt to micro-manage the establishment and continual re-establishment of different species assemblages as climate zones move. In our view, the progressive shifting of climatic zones makes a rewilding-centred approach even more appropriate. Such an approach allows species to establish as an autonomous, emergent process in ways that are ecologically appropriate in a dynamic situation of constant change.

NOW IS THE TIME TO THINK BIG AND ACT WILD

An urgent expansion of rewilding and nature's recovery is needed across at least 30% of Britain's land and seas by 2030 to match the scale of the threats from accelerating climate heating and species extinction. To achieve this we must see the establishment of much expanded rewilding areas where natural processes are allowed to govern and shape the land and seascapes. These should be embedded within a wider nature-friendly mosaic of land and marine uses that enhance nature's restoration. We see two complementary priorities:

1. CREATION OF CORE REWILDING AREAS

First, the creation of core rewilding areas across at least 5% of Britain to enhance and urgently expand the scale and ecological integrity of our marine and terrestrial protected areas and reserves. These areas should focus on restoring and reinstating as wide a range of natural processes, habitats and related species as possible to:

- Create wilder spaces across our marine and terrestrial protected areas that can serve as refugia and valuable 'landing pads' for range-shifting species
- Restore complete food webs and natural disturbance regimes – as well as structural and functional complexity – to increase ecosystem resilience
- Create multi-scale networks of refugia which span a broad range of climatic zones and gradients [46]
- Prioritise natural regeneration, or where this is demonstrably not possible, assisted regeneration to facilitate the establishment of more complex and locally adapted species assemblages.

2. ESTABLISHMENT OF 'NATURAL DISPERSAL CORRIDORS'

Second, the establishment of 'natural dispersal corridors' across at least 25% of Britain that embed core rewilding areas within broader mosaics of nature-friendly land and marine uses which enhance nature's recovery. Within these corridors we should:

- Substantially expand habitat quality and connectivity in a way that allows species to disperse and migrate as climate zones move
- Provide the hospitable, permeable habitats through which species can more easily move as they respond to climate heating
- Encourage the creation of a network of micro-refugia of favourable habitats to form holdouts or stepping stones across broad climatic and elevational gradients
- Prioritise and incentivise land and marine uses which enhance nature's restoration such as low-impact mixed forestry, harvesting of natural products, nature-based tourism and naturalistic grazing
- Facilitate species dispersal over barriers like major roads and other infrastructure.

These are not novel ideas: conservation groups have considered these issues for many years. What we are proposing is to bring urgency, scale, ambition and connectivity to the myriad of existing initiatives as well as inspiring new ones. These include the Nature Recovery Networks and National Ecological Networks (Marine and Terrestrial) in England and Scotland; existing large-scale projects such as Purbeck Heaths National Nature Reserve, Cairngorms Connect and Wild Ennerdale; projects focused on connectivity such as Buglife's B-Line Project; as well as a growing number of landowner and community-led initiatives such as the Langholm Moor Community Buyout, Knepp Estate and others.

In the following section, we explore some ways in which rewilding can help Britain's wildlife adapt to climate heating as an effective, complementary approach for those managing our land and seas.

LET NATURE LEAD – TAKING A REWILDING APPROACH

Individual species, and therefore ecological communities, have already started to shift in response to climate heating, and will do so increasingly in the future. This is true within protected areas and the wider countryside. The well-established practice of often intensive, fine-tuned habitat and species management to maintain sites in a pre-defined, static state, will be increasingly untenable and counter-productive. Large-scale rewilding provides space and freedom for nature to function dynamically.

This need to progressively step back from a species management-centred paradigm in many cases represents a challenge to existing conservation practice. It means letting go of subjective judgements about 'desirable', 'undesirable' and even 'non-native' species. So-called 'non-natives' in one place may well be refugees from another. However, this should only apply to species expanding their natural ranges with climate rather than invasive non-natives from much further afield introduced artificially by humans.

In the UK, the little egret has become well established in the south of the country in recent years after spreading north from the continent, possibly tracking the northward shift of its climate space. Collared doves and anchovies have likewise expanded their range from further south in Europe. However, these are clearly distinct from true invasives like Japanese knotweed, the slipper limpet, mink or signal crayfish in terms of their appropriateness for UK ecology. Rewilding will need to take into account the need to discourage true anthropogenic invasives from colonising new natural areas. Invasive marine species, such as the afore-mentioned slipper limpet and Pacific oyster, are effectively creating new habitats in shallow UK seas, both in the intertidal and subtidal areas. It is important to bear in mind that invasives more easily colonise broken ecosystems in which native species are missing or have been suppressed.

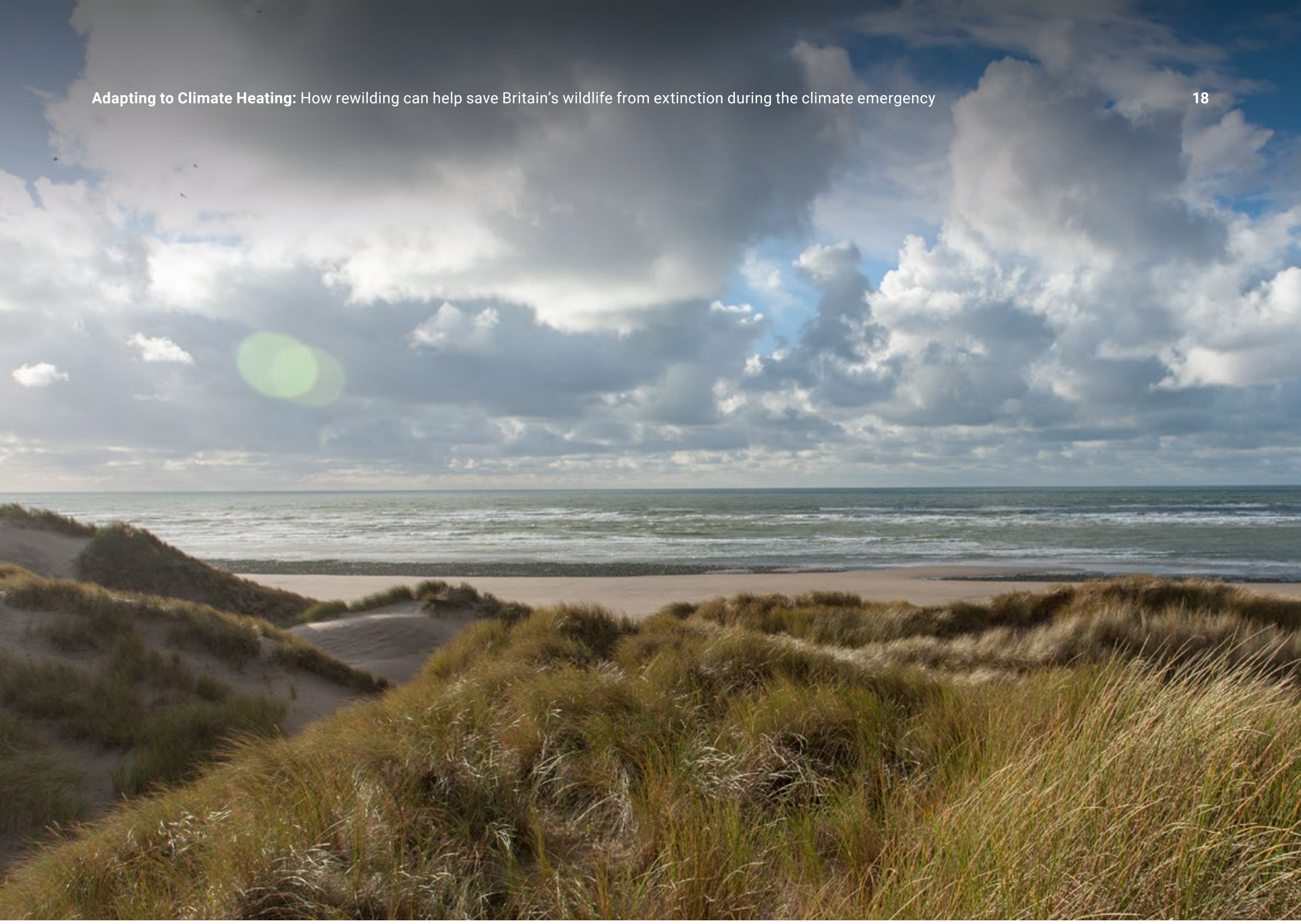
A rewilding-centred approach seeks to reinstate natural processes - including complete food webs and natural disturbance regimes - through natural regeneration and passive restoration wherever possible to create a rich mosaic of interconnected habitats. This means that traditional restoration approaches may no longer always be necessary or appropriate. For example, there is a large literature on the relative merits of active versus passive restoration of forests on logged or farmed areas. This suggests that passive restoration – an approach closer to rewilding in other words – is more effective than active tree planting in most (though not all) cases. This is in part because it supports mixed aged, local adapted stands with greater ecological complexity than planting alone would achieve.

One recent meta-analysis of 166 studies of naturally regenerating and actively restored forests worldwide concludes that 'planting trees did not result in consistently faster or more complete recovery than passively restored sites'. It adds that 'simply ending the land use is sufficient for forests to recover in most cases' [47]. One exception might be where a specific tree or shrub species is simply unable to work its way north or up-elevation due to intrinsic dispersal limitation or insurmountable anthropogenic barriers. For such species, highly targeted planting may be required to ensure it gets a safe foothold from which it can expand its population.

One somewhat contentious issue surrounds the use, or otherwise, of surrogates for extinct large browsers and grazers within rewilding projects. The now extinct aurochs and European wild horses were such fundamental components of dynamic European ecosystems that we consider the use of surrogates to be appropriate in many instances. Notwithstanding the over-abundance of smaller herbivores (i.e. deer), larger browsers and grazers are crucial sculptors of ecological succession. They can also form vegetation mosaics and natural fire breaks, reducing fire risk within the shrubby phase of ecological succession within dryer landscapes.

'Passive rewilding' approaches have been most widely and cost effectively demonstrated for restoring seas and their ecological function, showing that if you remove the pressure the system can often recover [48].

Favouring a rewilding-centred approach does not mean a complete absence of intervention. For example, dams may need to be removed on rivers, and important engineer species like beavers and raptors reintroduced and protected. Peat bogs, which are currently degraded and drained, will need to be re-wetted and protected from burning. Former grasslands may need to be 'scarified' to encourage saplings to sprout and establish, although wild boar can in some places perform this role as its



population recovers. In some places grazing will need to be actively controlled to ensure it remains at ecologically appropriate levels pending the return of predators. Plants and animals may need to be actively introduced into areas of suitable habitat.

Intertidal marine areas will need shoreline modification and engineering to allow for saltmarsh to be created in new inland areas as seas rise. Some areas of offshore seagrass can be re-seeded, while others can be protected from moorings by raising mooring chains and ropes off the seabed, reducing their abrasive impact [49]. Similarly, oyster 'cultch' can be laid, and juveniles placed on the material to regenerate recruitment from the wild[50].

These issues will need to be considered on a case-by-case basis, especially for species at serious risk of extinction or at such low levels that they're unable to recover. Some wader species, for example, may require 'intensive care', in the form of precise habitat management at a few sites, to enable them to rebound into more naturally-functioning wetlands. This is especially the case where species that are already of conservation concern are predicted to be worst hit by climate warming. A study on birds has found that red and amber-listed species, such as grey partridge, curlew, grasshopper warbler, ring ouzel, pied flycatcher and yellowhammer, will see significant population declines by 2080 due to climate warming. More common green-listed species may see populations increase[51].

Protected areas that span elevational gradients can be particularly valuable because, as noted earlier, species need only move uphill over much shorter distances than is required to move latitudinally to remain in their adapted climate zones[52]. Given that the majority of area in Britain's national parks is upland, including some of the highest parts of the three nations, the argument for rewilding them is thus strengthened further.

CREATING CONNECTIVITY THROUGH NATURAL DISPERSAL CORRIDORS

In the new age of climate and ecological emergency, connectivity is the key for climate adaptation. Rewilding can provide connectivity in a way that is most appropriate to a rapidly changing situation. Rewilding Britain proposes that core rewilding areas be embedded within broader mosaics of wildlife-friendly land and marine uses which enhance nature's recovery. Configured as natural dispersal corridors between rewilding areas, these mosaic land and seascapes should also provide hospitable, permeable habitats through which species can more easily move as they respond to climate heating.

Ecological corridors are not a new concept. In North America a huge wildlife corridor called 'Yellowstone to Yukon' (Y2Y) has been established, bringing together wilderness areas, wildlife refuges, and national, state and provincial parks over more than a thousand kilometres south to north connecting the United States to Canada via the natural chain of the Rocky Mountains[53]. Although this was not initially designed with climate adaptation in mind, it is now recognised that this will be a vital function of the Y2Y corridor in decades to come.

We would like to see a similar ambition for the scale of corridors across Britain's land and sea. Taking no predetermined or imposed path these corridors would aim to connect up, enhance, restore and expand Britain's most important habitats using core rewilding and protected areas as stepping stones. We suggest that areas within these dispersal corridors, land and marine uses should be incentivised which restore natural ecology to the maximum extent possible, thereby allowing species to move across them dynamically in complex ways that cannot be predicted and directly managed. For example, land managers should be financially incentivised through 'public payments for public goods' to support the restoration of nature in these areas as laid out in Rewilding Britain's previous report on restructuring agricultural subsidies[54]. Substantial efforts will also be needed to facilitate species dispersal over barriers like major roads. In other countries, for example, highways have been covered with special bridges where species need to migrate across them.

The corridors will provide a focal point for accelerating the natural regeneration of habitats such as woodland, saltmarshes and wetlands as well as the restoration and protection of peatbogs, heaths, and species-rich grassland/shrubland mosaics. In the face of climate warming this will bring dual benefits in terms of both climate adaptation and mitigation.

We do not propose that corridors should have hard borders, but instead should be graded into the landscape. Giving local people a real influence over and say in decisions made about the way that the land and sea is managed is key. Local and government action can build on the wave of interest that the declarations of climate and ecological emergencies have stimulated. Those who own and derive their income from the land and sea are central to decision-making and should be supported. Land managers should be financially incentivised through 'public payments for public goods' to support the restoration of nature in these areas as laid out in Rewilding Britain's previous report on restructuring agricultural subsidies[55].

APPENDIX

APPENDIX 1: POTENTIAL SPECIES LOSS SCENARIOS

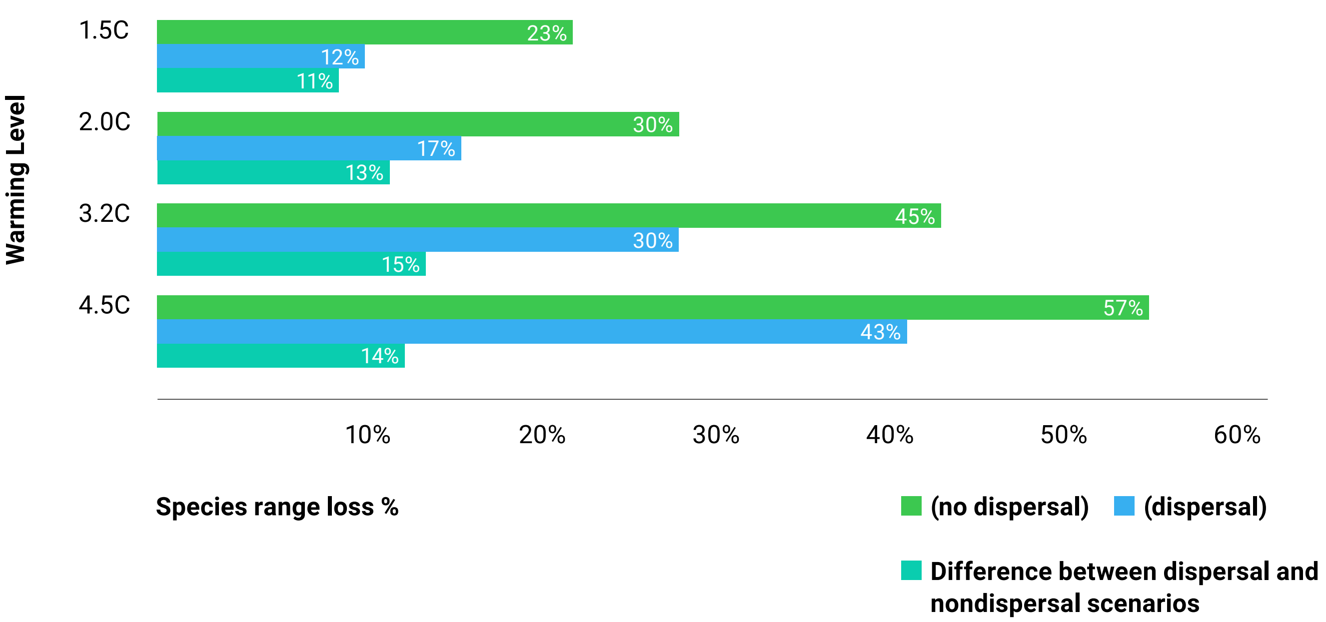
Quantifying the potential species loss arising in different scenarios can only be an illustrative effort given the substantial uncertainties involved in species distribution modelling, but likely magnitudes can be indicated by examining the dispersal/no dispersal scenarios of Thomas et al (2004)[56] and Warren et al (2018) [57] approaches.

For example, Thomas et al calculated that with minimum climate change and maximum dispersal, the number of species 'committed to extinction' globally by 2050 could be as low as 9-13%. For no dispersal and maximum climate change the number of species committed to extinction ranged from 38-52%. Thus with strong mitigation and a conservation approach that successfully allows maximum dispersal, at most 43% of species could be saved that would otherwise be committed to extinction.

However, if we are to compare like for like climate scenarios in order to see the benefits of dispersal only (as opposed to including mitigation) Thomas et al see 9-13% of species lost in a minimum climate warming scenario with dispersal, as compared to 22-31% of species lost in the same minimum climate warming scenario with no dispersal. Under maximum climate change these figures rise to 21-32% (with dispersal) to 38-52% (no dispersal). There is therefore a roughly 15-20% benefit in avoiding extinction by allowing dispersal in their model. A tentative conclusion therefore might be that rewilding – if it allows higher dispersal scenarios which would otherwise not occur – could save a significant fraction (up to a fifth) of UK species from climate-related extinction. However, this would depend on the ability and mobility of species to actually disperse at a rate that keeps up with shifting climate zones. As discussed earlier, this might be possible for fast-moving animal species but is unlikely for long-lived and slow-dispersing trees and other plants. It is therefore impossible at present to quantify numerically with any confidence the possible benefits to biodiversity of such an approach.

For Warren et al, the differences between dispersal and no-dispersal scenarios can be deduced from their table, amended from earlier:

The mean of the difference from all the warming scenarios is about 13%, implying that on average allowing full dispersal avoids the loss of about 13% of habitat due to warming. This figure is not directly comparable to Thomas et al discussed above as those authors are projecting species loss while Warren et al are projecting loss of habitat. Even so, both papers clearly demonstrate a significant benefit to allowing species dispersal in climate warming scenarios, indicating that a substantial fraction of UK wildlife might be saved from habitat loss or outright extinction if rewilding facilitates this process successfully.



APPENDIX 2

1 Ceballos, G et al, 2015: ' Accelerated modern human–induced species losses: Entering the sixth mass extinction', Science, 1:5, e1400253
2 Rewilding Britain, 2019: Rewilding and Climate Breakdown – how restoring nature can help decarbonise the UK. https://www.rewildingbritain.org.uk/assets/uploads/Rewilding%20and%20Climate%20Breakdown%20-%20a%20report%20by%20Rewilding%20Britain.pdf
3 See appendix 1 for the assumptions and justifications for this calculation.
4 Hayhow, D et al., 2016: State of Nature 2016. The State of Nature Partnership. https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/state-of-nature-uk-report-2016.pdf p.71
5 Rewilding Britain, 2019: Rewilding and Climate Breakdown - how restoring nature can help decarbonise the UK. https://www.rewildingbritain.org.uk/assets/uploads/Rewilding%20and%20Climate%20Breakdown%20-%20a%20report%20by%20Rewilding%20Britain.pdf
6 Burrows, M. T. et al. Geographical limits to species-range shifts are suggested by climate velocity. Nature 507, 492–495, https://doi.org/10.1038/nature12976 (2014).
7 Settele, J et al., 2014: Terrestrial and inland water systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p297.
8 'High-emissions scenario' is RCP 8.5, while a 'more moderate emissions scenario' is RCP 4.5 in IPCC parlance. See https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario for a helpful explainer.
9 Poloczanska, E et al., 2014: Cross-chapter box on observed global responses of marine biogeography, abundance, and phenology to climate change. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 123-127.
10 Sandel, B et al., 2011: ' The Influence of Late Quaternary Climate-Change Velocity on Species Endemism', Science, 334:6056, pp. 660-664. Supplementary info text gives a (very conservative) mean of 1498m/yr for future climate warming, vs 5.94m/yr after the Last Glacial Maximum. Our figure of 5000m/yr means a climate velocity over 800 times faster than after the LGM.
11 Wagner, S & Lundqvist, L, 2005. Chapter 10, 'Regeneration techniques and the seedling environment from a European perspective', in Stanturf, J & Madsen, P (eds), Restoration of Boreal and Temperate Forests, CRC Press
12 Pearson, R, 2006: ' Climate change and the migration capacity of species', Trends in Ecology & Evolution, 21:3, pp 111-113.
13 Gray, L & Hamman, A, 2012: ' Tracking suitable habitat for tree populations under climate change in western North America', Climatic Change, 117, pp289-303.
14 Bertrand, R et al., 2011: ' Changes in plant community composition lag behind climate warming in lowland forests', Nature, 479, pp 517–520.
15 Settele, J et al., 2014: Terrestrial and inland water systems. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p297.
16 Warren, R et al., 2018: ' The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C', Science, 360, 791–795. Supplementary Material.
17 Bedford, F et al., 2012: ' Systemic range shift lags among a pollinator species assemblage following rapid climate change', Botany, 90, 587–597.
18 Settele, J et al., 2014: Terrestrial and inland water systems. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p295.
19 Devictor, V et al., 2008: 'Birds are tracking climate warming, but not fast enough', Proceedings of the Royal Society B, 275:1652.
20 Mason, C et al., 2015: 'Geographical range margins of many taxonomic groups continue to shift polewards', Biological Journal of the Linnean Society, 115:3, pp 586–597.
21 Kerr, J et al., 2015: 'Climate change impacts on bumblebees converge across continents', Science, 349:6244, pp. 177-180.
22 Hoegh-Guldberg, O et al., 2014: The Ocean. In Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. p.1667
23 Poloczanska, E et al., 2014: Cross-chapter box on observed global responses of marine biogeography, abundance, and phenology to climate change. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 123-127.
24 Lenoir, J et al., 2020: 'Species better track climate warming in the oceans than on land', Nature Ecology & Evolution, 4, 1044–1059
25 Hiddink, J et al., 2014: 'Temperature tracking by North Sea benthic invertebrates in response to climate change', Global Change Biology, 21:1, 117-129,
26 Ratcliffe, R, undated: 'Seabirds in Danger', RSPB. https://www.rspb.org.uk/get-involved/campaigning/climate-change-effects-on-nature-and-wildlife/effects-of-climate-change-on-wildlife/starving-seabirds/seabirds-in-danger/
27 Beaugrand, G et al., 2003: 'Plankton effect on cod recruitment in the North Sea', Nature, 426, 661-664.
28 Macdonald, A et al., 2015: Climate-driven trophic cascades affecting seabirds around the British Isles. In: Oceanography and Marine Biology: An Annual Review. 53, 55-79.
29 Thomas, C et al, 2004: 'Extinction risk from climate change', Nature, 427, 145-148.
30 Warren, R et al., 2018: ' The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C', Science, 360, 791–795.
31 Warren, R et al., 2018: ' The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C', Science, 360, 791–795. Supplementary Materials. Adapted and calculated by averaging all taxa from Tables S3 and S5.
32 Solandt, J-L, 2018: ' A stocktake of England's MPA network – taking a global perspective approach', Biodiversity, April 2018.
33 Gilbert, G et al, 2010: ' Current dynamics and predicted vulnerability to sea-level rise of a threatened Bittern Botaurus stellaris population', Ibis, 152, 580-589.
34 Avery, M, undated: Torrential rain - a blow to bittern recovery. RSPB. https://www.rspb.org.uk/get-involved/campaigning/climate-change-effects-on-nature-and-wildlife/effects-of-climate-change-on-wildlife/flooding-devastation/a-blow-to-bittern-recovery/
35 Barkham, P, 2018: ' Britain's biggest butterfly threatened by rising seas', The Guardian, 29 June 2018. https://www.theguardian.com/environment/2018/jun/29/sea-level-rise-could-wipe-out-swallowtail-butterfly-in-40-years
36 Santangeli, A et al., 2017: 'Effects of high latitude protected areas on bird communities under rapid climate change', Global Change Biology, 23, 2241–2249.
37 Thomas, C & Gillingham, P, 2015: 'The performance of rotected reas for biodiversity under climate change', Biological Journal of the Linnean Society, 115, 718–730.
38 Hiley, J et al., 2013: 'Protected areas act as establishment centres for species colonizing the UK', Proceedings of the Royal Society B, 280:1760.
39 Carroll, C & Noss, R, 2020: 'Rewilding in the face of climate change', Conservation Biology, in press.
40 British Trust for Ornithology. 'Climate change in a warming world'. https://www.bto.org/our-science/case-studies/climate-change-warming-world
41 Oliver, T et al., 2017: 'Large extents of intensive land use limit community reorganization during climate warming', Global Change Biology, 23:6, 2272-2283.
42 Pearce-Higgins, P & Gillings, S, 2017: 'Large extents of intensive land use limit community reorganization during climate warming', BTO. https://www.bto.org/our-science/publications/peer-reviewed-papers/large-extents-intensive-land-use-limit-community

43 Lenoir, J et al., 2020: 'Species better track climate warming in the oceans than on land', Nature Ecology & Evolution, 4, 1044–1059
44 Rewilding Britain, 2019: Rewilding and Climate Breakdown - how restoring nature can help decarbonise the UK. https://www.rewildingbritain.org.uk/assets/uploads/Rewilding%20and%20Climate%20Breakdown%20-%20a%20report%20by%20Rewilding%20Britain.pdf
45 See appendix 1 for the assumptions behind this calculation.
46 Carroll, C & Noss, R, 2020: 'Rewilding in the face of climate change', Conservation Biology, in press.
47 Meli, P et al, 2017: ' A global review of past land use, climate, and active vs. passive restoration effects on forest recovery', 12(2): e0171368.
48 Tinsley, P, 2020: Chapter 12 - Marine protected areas in the UK – conservation or recovery? In: Marine Protected Areas - Science policy and management, [Humphreys, J & Clark, R., eds] pp 217-236 Tinsley, P, 2020: Chapter 12 - Marine protected areas in the UK – conservation or recovery? In: Marine Protected Areas - Science policy and management, [Humphreys, J & Clark, R., eds] pp 217-236
49 Luff, A et al., 2019: 'A simple mooring modification reduces impacts on seagrass meadows', Scientific Reports, 9, 20062.
50 Heriot-Watt University. 'Scientists aim to restore oyster population'. https://www.hw.ac.uk/research/impact/environment/scientists-aim-to-restore-oyster-population.htm
51 British Trust for Ornithology, 2017. 'Projected reductions in climatic suitability for vulnerable British Birds'. https://www.bto.org/our-science/publications/peer-reviewed-papers/projected-reductions-climatic-suitability-vulnerable
52 Elsen, P et al., 2018: 'Global patterns of protection of elevational gradients in mountain ranges', PNAS, 115:23, 6004-6009.
53 See https://y2y.net/
54 Rewilding Britain, 2019: Rewilding and Climate Breakdown - how restoring nature can help decarbonise the UK. https://www.rewildingbritain.org.uk/assets/uploads/Rewilding%20and%20Climate%20Breakdown%20-%20a%20report%20by%20Rewilding%20Britain.pdf
55 Rewilding Britain, 2019: Rewilding and Climate Breakdown - how restoring nature can help decarbonise the UK. https://www.rewildingbritain.org.uk/assets/uploads/Rewilding%20and%20Climate%20Breakdown%20-%20a%20report%20by%20Rewilding%20Britain.pdf
56 Thomas, C et al, 2004: 'Extinction risk from climate change', Nature, 427, 145-148.
57 Warren, R et al., 2018: ' The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C', Science, 360, 791–795. Adapted and calculated by averaging all taxa from Tables S3 and S5.

PHOTOGRAPHY CREDITS

Cover	Chris Hill/Shutterstock
Page 5	Valentin Petkov
Page 6	Charles Lamb
Page 7	Peter Cairns/scotlandbigpicture.com
Page 8	Ivana Cajina
Page 9	Michael Blum
Page 12	Ramon Vloon
Page 14	AlessandroZocc/Shutterstock
Page 16	Ben Porter
Page 19	Mark Hamblin/scotlandbigpicture.com