UK Parliament POST

POSTNOTE

Number 679 October 2022

Climate adaptation for nature

The UK Government has committed to halting the long-term decline of species abundance and protecting 30% of land and sea by 2030. Achieving this will require consideration of the impacts of climate change on wildlife and their ecosystems. This POSTnote summarises options to allow nature to adapt to a changing climate and ensure the long-term effectiveness of conservation strategies.

Overview

- Climate change will have impacts on the survival of species, their geographic range, and the condition of the areas they occupy.
- Conservation strategies to achieve nature recovery will have to consider these climate impacts if they are to deliver stated aims.
- Effective monitoring would enable a dynamic approach where conservation priorities are adapted over time as species and ecosystems respond to climate change.
- Minimising other pressures on wildlife can reduce the potential impacts of climate change and facilitate species migration.
- Strategies for climate adaptation include providing diverse conditions within ecosystems for wildlife, improving connectivity between these areas, restoring ecosystems, and moving species if needed.

Background

The decline in UK biodiversity, the variety of ecosystems and species within nature and their interactions (PN 617), has been well documented.[1–4] The widespread social and economic impacts of biodiversity loss were highlighted in the Dasgupta Review.[5] The UK Government has committed to halting this decline and protecting 30% of land and sea by 2030 (30x30).[6,7] The 2021 UK Climate Change Risk Assessment highlighted the urgent need for adaptation measures for terrestrial, marine and freshwater species.[8] The Third National Adaptation Programme for England, due in 2023, and equivalent plans in Wales, Scotland and NI, set out actions to address climate risks to biodiversity.[9] A suite of biodiversity targets for England currently being consulted on include increasing species abundance by 10% by 2042.[10] However, the Office for Environmental Protection (OEP) warned that the targets do not sufficiently consider climate risks.[11]

To address long-term biodiversity decline, the UK Government's 25 Year Environment Plan (25YEP) for England, proposed establishing a Nature Recovery Network (NRN) to restore and create wildlife-rich habitats and enhance existing protected areas (PAs) (Box 1). The NRN's design will be based on recommendations in the 2010 Lawton report,[12] including that PAs need to be "more, bigger, better and joined up" to reverse biodiversity loss (Box 2).[13] Public authorities are also expected to prepare and publish local nature recovery strategies (LNRS)[14] to identify opportunities for ecosystem restoration to increase levels of biodiversity and realise wider environmental benefits (PN 652). It is important to note that, while the scientific principles are applicable across the UK, policy on nature conservation is devolved. As such, the framework for NRN and LNRS only applies to England with similar policies for Wales, Scotland and NI.

Conservation priorities may have to change to consider the impacts of climate change. For example, PAs may become climatically unsuitable for the species and features they were designated for but may become suitable for others.[15–20] Species composition within PAs may change as species' geographic ranges shift in response to changing climatic conditions and extreme climate events such as droughts,[21] heatwaves,[22] floods,[23] storms,[24] and wildfires.[25]

Impacts of climate change on biodiversity

Climate change interacts with other stressors to drive ecological change (PN 617). Major impacts on UK biodiversity include:

- **Shifting distributions** - Many UK terrestrial species have shifted northwards or uphill.[26–28] This is projected to continue with future warming but the speed of change varies between species.[29,30] This could lead to the loss of cold-associated

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Box 1: Designations of Protected Areas in the UK
The main PA designations are:
- **Sites of Special Scientific Interest (SSSI)** – designated to conserve wildlife, geology or landform features. SSSI designation is a devolved matter. They are equivalent to Areas of Special Scientific Interest in NI.
- **Special Protected Areas (SPA)** – designated under the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations[31] to protect habitats for migratory birds.
- **Special Areas of Conservation (SAC)** – designated under the same legislation as SPAs to conserve listed terrestrial, freshwater, and marine habitats.
- **Ramsar sites** – designated under the UNESCO Ramsar Convention as protected wetlands
- **National Nature Reserves (NNR)** – designated for public access and research. Their designation is a devolved matter. **Local Nature Reserves (LNR)** are designated by local authorities for local interest.
- **Marine Protected Areas (MPAs) - Marine Conservation Zones (MCZ) –** designated under the Marine and Coastal Act 2009 for threatened marine species and habitats. Defra is consulting on **Highly Protected Marine Areas (HPMAs)** where "destructive" fishing and dredging activities will be prohibited.[32]
- **Areas of Outstanding Natural Beauty (AONB) and National Parks** – designated under the National Parks and Access to Countryside Act 1949 for natural beauty, cultural heritage, and recreational purposes. They are equivalent to National Scenic Areas in Scotland

species but a net gain of mobile species spreading north from Europe.[30,33] The range of some freshwater fishes may contract,[34] but the pattern is less clear due to interactions with local water quality (PN 661).[35,36] Marine species have shifted to colder regions six times more quickly on average than terrestrial species.[37,38] Invasive non-native species may increase in abundance and some species could become invasive under higher temperatures (PN 673).[39,40]

- **Disrupted life cycles -** changing weather patterns alter the seasonal timing of species' life cycles and can lead to ecological mismatches[41–44] (such as flowering date and availability of pollinators[45,46]). Projected reduced summer river flows across the UK,[21] may negatively impact freshwater ecosystems.[47,48]
- **Lower survival rates -** extreme climate events can affect species survival at all life stages,[49,50] and cause damage to ecosystems they rely on. For example, sensitive butterfly species experienced population crashes during past droughts,[51] and local extinctions may occur as droughts become more severe.[52] Climate change may result in more persistent marine heatwaves[53] affecting species such as shellfish (PN 604 and 651).[54–56]
- **Habitat loss -** for example, sea level rise will affect coastal habitats through saltwater intrusion and erosion. Low-lying intertidal habitats, such as saltmarsh and shingle, are vulnerable to 'coastal squeeze' between infrastructure and rising sea levels (PN 647).[57,58]

Adapting management to climate change

Traditional conservation objectives tend to be static, such as maintaining species and ecosystems in a particular area.[20,59–61] PAs have legally designated features, habitats or species over specific geographic areas that give them their scientific interest,[62] which constrains what management options can be

Box 2: Ecological resilience
There are differing definitions of ecological resilience (PN 543). Researchers distinguish between:[63,64]
- **Resistance** – the ability of species or ecosystem functions to remain stable under climate change.
- **Recovery** – the ability of species or ecosystem functions to return to a pre-disturbance state.
- **Resilience** – A combination of resistance and recovery, including the ability of species or ecosystem functions to recover from disturbance and absorb change.

applied.[59,61,65] However, there is increasing evidence that active management targeted at vulnerable species can help reduce the impacts of climate change on them.[66] Given the uncertainty in the speed and magnitude of climate impacts, researchers recommend adaptive management to re-evaluate management options over time, notably when objectives change.[60,67–69] Ecological responses to climate change are dynamic and adaptive management requires sufficient monitoring to inform approaches at both the site and network level.[70,71] Adaptive management approaches currently in use include:

- **Resist-Accept-Direct (RAD)** - this framework (Box 3) classifies climate adaptation options (see next section) into three strategies along a continuum with increasing acceptance of ecological change.[72–74] Natural England is considering using the RAD framework to inform the choice of adaptation options over time.[75] Somerset Wildlife Trust is adopting the RAD framework to plan for the possible transition of mature woodlands to wood pastures with fewer trees due to increasing impacts of extreme climate events.[76]
- **Adaptation pathways** – this approach (Box 4) is a planning tool co-created with stakeholders to map out different routes to achieve a defined objective.[77] Different pathways and options to achieve favourable outcomes (such as increasing species abundance and genetic diversity) are considered. This includes evaluating trade-offs with other sectors such as electricity generation and water supply.[78]

Conservation options for climate adaptation

Improve management of existing PAs

PAs may facilitate range expansion or movement for species' populations if high quality habitats are available.[79,80] The Environmental Audit Committee recommended that only effectively managed PAs should count towards the 30x30 target.[67] Although 28% of total UK land area is under protected status,[62] only 11.4% is primarily designated for conservation. As around only half or less of this meets "favourable condition" status,[81] nature is only effectively protected in ~5% of the total land area.[82] If conservation is prioritised in AONBs and National Parks to sufficiently improve the quality of habitats, their large size may significantly increase the area effectively managed.[16,83]

Minimising other pressures can increase biodiversity's resilience to climate-related shocks.[60,84,85] For example, restricting bottom towed fishing in the Lyme Bay MPA enhanced the ability of coastal reefs to recover after winter storms.[86] However, most of the UK's MPAs have yet to fully implement management plans or place restrictions on bottom towed fishing.[60,61,87,88] Sustainable land management (PB 42) and catchment-based approaches (PN 661) can mitigate non-climate pressures, such as pollution and over-abstraction of water resources (PB 40).

Box 3: Resist-Accept-Direct (RAD)

The three sequential options of the RAD framework are:

- **Resist** change by preserving historical and current conditions. The persistence of designated features is the dominant management objective within NNRs.[65,89]
- **Accept** change by accommodating new species and ecosystems. This could include accepting that local losses may be inevitable[90] but could be tolerated if the species thrive elsewhere.[91]
- **Direct** change by proactively directing transition to a new ecosystem state compatible with future. Some researchers have described this approach using such terms as facilitate or transformation.[63,91,92]

For example, at the southwest Wales Bosherston Lakes NNR, a rare shallow freshwater marl lake system,[93] Natural Resources Wales (NRW) aims to maintain habitat persistence by extensive catchment management to limit nutrient runoff and manage external pressures in the short term.[94] In the medium term, NRW aim to enhance protection of certain sections of the lake system and reduce management efforts at the most vulnerable sections if the speed of sea level rise accelerates and if water quality changes significantly due to low water levels and warmer temperatures.[94] In the long-term, NRW plans for a managed transition to allow parts of the Bosherston Lakes NNR to transition to brackish conditions with further sea level rise.[94]

Practitioners suggest a more joined up approach, with the objectives of the NRN informing policies,[95] such as the Environmental Land Management Schemes (ELMS)[67] and the new Land Use Framework for England.[96]

Ensure diverse conditions within ecosystems

Microclimates, localised climatic conditions arising from a diversity of landform features, form safe havens for species despite declining climate suitability.[97–99] Research showed that the extinction risk of threatened UK plants, butterflies and insects can be reduced by protecting diverse habitat features, such as dips and hummocks.[100–102] The Banking for Butterflies project in Bedfordshire created artificial multi-directional shelters to maintain microclimates.[103] Diverse ecosystems can help rare species constrained by narrow geographic ranges to overcome negative land use and climate impacts.[104,105] For example, cold-associated upland birds and plants are likely to increasingly rely on cooler north-facing slopes.[106,107] Tree planting on river banks can provide local shading and maintain areas with cooler river temperatures for freshwater species.[108–110] Protecting deeper waters can also help retain marine species shifting their geographic and depth ranges.[111]

Improve connectivity for species movement

Existing terrestrial PAs protect semi-natural habitats and are targets for species shifting their ranges.[79,112–115] However, more connected PAs are likely to have higher species richness.[116,117] One application of decision support tools is identify the configuration of measures to maximise species dispersal.[118] These can include Other Effective area-based Conservation Measures (OECMs) (Box 5) or measures that deliver:[59,119]

- **Ecological corridors** – space between PAs to allow species to move, forage and reproduce, and for the flow of genetic material. This includes landscape features such as hedgerows. CPRE is calling for a 40% increase in the UK's hedgerow network extent by 2050.[120]

Box 4: Adaptation pathways

The adaptation pathways approach is a scenario planning tool widely used in water and flood management.[77,121,122] It identifies critical thresholds beyond which additional actions or alternative management approaches are needed.[77] The cost and benefit for each pathway after reaching a tipping point reflects the socially acceptable cost of certain actions and the level of risk individual stakeholders are willing to take.[123]

Adaptation pathways have been developed in the UK to map out management actions over time to protect coastal communities from sea level rise.[123,124] For example, if the frequency of waves overtopping coastal defences exceed a threshold, maintaining or upgrading them may not be sustainable (PN 647).[123] The "Adapting the Levels" project co-created pathways with local stakeholders at the Somerset Levels and Moors Ramsar site.[125] Pathways showed that local water and soil management may become unsustainable beyond a 30% increase in rainfall. Then measures such as redirecting river reaches and converting arable land to wood pastures are more acceptable pathways.[125]

- **Buffer zones** – transitional areas around PAs with nature-friendly land use. For example, NatureScot is enhancing the ability of montane willow scrubs to disperse across disparate PAs by varying grazing levels and created fenced areas in the intervening landscapes between PAs.[126]
- **Stepping stones** – smaller, separated areas of habitats designed to connect core PAs. Stepping stones, such as farmland ponds to allow aquatic species movement,[127] strategically located to encourage north-south movement are particularly effective to improve overall connectivity.[128]

In freshwater ecosystems, physical barriers such as dams and culverts impede latitudinal (up- and down-stream) and lateral (channel and floodplains) movement of freshwater species.[129–131] However, ecologically friendly culvert designs and other Green Infrastructure (PB 26) can reinstate the natural river flow regime, reduce flooding and enable fish movement.[129,132] The Environment Agency River Obstacles database maps large barriers on major rivers,[133] which has been used in projects, such as to improve eel migration in the Thames catchment.[134] There remains a lack of data for structures in smaller streams, limiting understanding of their impacts on connectivity.[135]

There is also a need to enhance connectivity across administrative boundaries. Researchers highlight the need to align local priorities with regional targets to avoid maladaptation or missed conservation opportunities (PN 652).[60,95] Issues may also arise for cross-border PAs, such as wetlands between Northern Ireland and the Republic of Ireland.[136,137] A Natural England project is evaluating how PA legislation can be effective under climate change, such as adjusting designated features over time.[59,138] For MPAs, marine spatial planning in England considers the ability of organisms and material, such as nutrients, to move between them (PN-388).[60,139] A UKRI funded project is looking at how marine spatial plans may change due to near term climate change.[140]

Ecosystem restoration

Ecosystem restoration can prevent or delay species loss, particularly at their southern range.[66,141–143] For example, the

RSPB enabled the expansion of Bitterns by creating inland reedbeds to reduce their dependency on coastal sites vulnerable to sea level rise.[144,145] Ecosystem restoration approaches are varied (PB 48; PN 678). Management objectives influence the approach to restoration from intensive restoration of sites to a historical state to minimal intervention approaches such as rewilding (PN 537).[146–148] Restored ecosystems support larger species populations,[149] even if the primary objective is other than conservation.[150–152] For example, restoration of kelp forests to increase carbon sequestration (PN 651) also provides storm protection and economic benefits for fisheries.[153] Other restoration to increase carbon sequestration include tree planting (PN 636), peatland (PN 668) and saltmarsh restoration (PN 647). Ecosystem restoration is also key to maintaining long-term water quality and quantity, such as wetlands restoration (PN 661),[154,155] and beaver reintroduction.[76,156] The Well-being and Future Generations (Wales) Act includes goals for restoration to benefit climate mitigation, nature recovery and social wellbeing.[157]

However, there may be limits to the role of restoration.[158] For example, groundwater levels at wetlands in southern England, including those recently restored, are projected to reduce with climate change, creating difficulties for the long-term maintenance of water levels.[159–161] Sites drying out lead to changes in vegetation and coastal sites may transition to brackish conditions with sea level rise.[89,159]

In addition, there are evidence gaps. For example, Forest Research recommends increasing species and age diversity within woodlands for climate resilience,[162] but the best mix of woodland species to improve resilience to extreme climate events is unclear.[163] In addition, tree planting should consider the impacts of climate change to avoid unintended consequences,[151,152] such as taking up water and exacerbating future droughts in some areas.[164] Native tree species such as beech may struggle from increasing drought severity in southeast England despite its climate mitigation potential (PN 636).[165,166] Commercial forestry near open and semi-open habitats can also negatively affect climate adaptation measures for priority species such as upland birds.[142,167]

Translocation and assisted migration

Translocation is the deliberate movement of species to alternative habitats with more suitable climatic conditions.[168,169] The circumstances under which management should actively translocate species for climate change adaptation is unclear. Some researchers suggest that translocation should be a "last resort" if a species is unable to survive in existing habitats, expand their range naturally or where there is limited habitat creation potential.[84,90] For example, alpine lichens in the Cairngorms were translocated to overcome their limited range in anticipation of future impacts.[170] Translocation of rare species, such as those on the IUCN Red List,[91,171] as a last resort may be expensive but may be the only way to prevent national extinction. Some researchers also advocate moving widespread species beyond their known ranges in the recent past.[172] For example, translocating butterflies from continental Europe to supplement decline of their richness in southern England.[91] The Wildlife and Countryside Link recommends defining in law a "Favourable Conservation Status" for species and to provide guidelines and parameters for when interventions are taken.[143]

Box 5: Other Effective area-based Conservation Measures (OECMs)

OECMs are areas other than a designated PA that can deliver conservation outcomes equivalent to those provided by PAs through:[16,173–175]

- Management where conservation is not an objective, but biodiversity outcomes are realised as a side effect, such as nature-based solutions for carbon sequestration (PN 617).
- Conservation designated as a secondary objective.
- Conservation as the primary objective, but not formalised as a designated PA.

The ambition for OECMs to contribute to 30x30 is reflected in the Nature Recovery Green Paper,[7] but they are currently not formalised in UK policy guidance for practitioners.

Functionally diverse ecosystems, where species support a range of ecological functions, such as decomposition and nutrient cycling, have greater climate resilience.[148,176,177] Translocating native species may retain the functions provided by climate-threatened species,[178] and translocating non-native species may replace lost functions.[91] However, the impacts to overall biodiversity from introducing non-native species is unclear.[179,180] Translocation may be costly and its effectiveness relies on well managed and connected recipient ecosystems.[138,181] The Scottish,[182] and English[183] guidance for conservation translocations provide guidelines to minimise the risk of invasive species (PN 673) and potential pests and diseases.

Monitoring conservation outcomes

Indicators used to monitor progress in climate adaptation reflect different priorities such as maintaining species persistence or facilitate ecological change.[71,184] For example, if the objective is to adapt to change, indicators of both native species and overall abundance are needed as native species may decline but overall abundance may increase.[91] Indicators can also assess whether overall pressures on biodiversity are reduced (PN 644). Possible indicators can be separated into:[184]

- **Process-based** – track the conditions and actions needed to enable short-term responses to adaptation (such as PA extent, habitat quality and change in connectivity[185]).
- **Results-based** – assess effectiveness of conservation, restoration, and adaptation over long time frames against different scenarios (such as species persistence, ecosystem functions or total species abundance). For example, comparing sites with and without measures can determine baselines in the absence of adaptation actions.[186]

However, the long-term effectiveness of measures are rarely assessed because of the lack of detailed records and the time lag between implementation and response.[71,187,188] The RSPB recommend that legally binding targets and expanded funding for monitoring in PAs are needed.[189] Improving habitat and species representativeness,[190–194] in PAs and long-term datasets, can monitor new species arrival[195] and avoid underestimating extinction risk.[196] Marine[18] and terrestrial[197] sentinel sites with minimal human influences can also monitor change and provide early warning of future threats.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Wilson Chan for researching this briefing, to NERC SCENARIO DTP for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.

References

1. Biodiversity Intactness Index data | Natural History Museum. *Biodiversity indicators | Natural History Museum*.
2. Hayhow, D. B. *et al.* (2019). The State of Nature 2019. The State of Nature partnership.
3. Environment Agency (2022). Working with Nature - Chief Scientist's Group report. Environment Agency.
4. JNCC (2021). UKBI - Overview of trends 2021.
5. Dasgupta, P. (2021). *The economics of biodiversity: the Dasgupta review: full report*. HM Treasury.
6. HAC for Nature and People. *HAC for Nature and People*.
7. Defra (2022). Nature Recovery Green Paper: Protected Sites and Species. Defra.
8. Berry, P. *et al.* (2021). Natural environment and assets. in *The Third UK Climate Change Risk Assessment Technical Report*. Climate Change Committee.
9. Defra (2022). Climate change adaptation: policy information. *GOV.UK*.
10. Defra (2022). Defra environmental targets consultation: Environment Agency response. *GOV.UK*.
11. Office for Environmental Protection (2022). OEP response to consultation on environmental targets.
12. Defra (2022). Nature Recovery Network. *GOV.UK*.
13. Lawton, J. H. *et al.* (2010). Making Space for Nature: a review of England's wildlife sites and ecological network. Defra.
14. Environment Act 2021. Queen's Printer of Acts of Parliament.
15. Pearce-Higgins, J. *et al.* (2011). Final Report to the Climate Change Impacts on Avian Interests of Protected Area Networks (CHAINSPAN) Steering Group.
16. Bailey, J. *et al.* (2022). Protected Areas and Nature Recovery: Achieving the goal to protect 30% of UK land and seas for nature by 2030. British Ecological Society.
17. Gaston, K. J. *et al.* (2006). The ecological effectiveness of protected areas: The United Kingdom. *Biological Conservation*, Vol 132, 76–87.
18. Rees, S. E. *et al.* (2020). Emerging themes to support ambitious UK marine biodiversity conservation. *Marine Policy*, Vol 117, 103864.
19. Frost, M. *et al.* (2016). A review of climate change and the implementation of marine biodiversity legislation in the United Kingdom. *Aquatic Conservation: Marine and Freshwater Ecosystems*, Vol 26, 576–595.
20. Elsen, P. R. *et al.* (2020). Keeping pace with climate change in global terrestrial protected areas. *Sci. Adv.*, Vol 6, eaay0814.
21. Kay, A. L. *et al.* (2021). Climate change effects on indicators of high and low river flow across Great Britain. *Advances in Water Resources*, Vol 151, 103909.
22. Arnell, N. W. *et al.* (2022). The impact of climate change on policy-relevant indicators of temperature extremes in the United Kingdom. *Climate Resilience and Sustainability*, Vol 1, e12.
23. Sayers, P. *et al.* (2021). *Third UK Climate Change Risk Assessment (CCRA3) Future flood risk projections*.
24. Harley, M. D. *et al.* (2022). Single extreme storm sequence can offset decades of shoreline retreat projected to result from sea-level rise. *Commun Earth Environ*, Vol 3, 1–11.
25. Arnell, N. W. *et al.* (2021). The effect of climate change on indicators of fire danger in the UK. *Environ. Res. Lett.*, Vol 16, 044027. IOP Publishing.
26. Hickling, R. *et al.* (2006). The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology*, Vol 12, 450–455.
27. Mason, S. C. *et al.* (2015). Geographical range margins of many taxonomic groups continue to shift polewards. *Biological Journal of the Linnean Society*, Vol 115, 586–597.
28. Gillings, S. *et al.* (2015). Directionality of recent bird distribution shifts and climate change in Great Britain. *Global Change Biology*, Vol 21, 2155–2168.
29. Massimino, D. *et al.* (2017). Projected reductions in climatic suitability for vulnerable British birds. *Climatic Change*, Vol 145, 117–130.
30. Pearce-Higgins, J. W. *et al.* (2017). A national-scale assessment of climate change impacts on species: Assessing the balance of risks and opportunities for multiple taxa. *Biological Conservation*, Vol 213, 124–134.
31. UK Government (2019). The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019. Queen's Printer of Acts of Parliament.
32. Defra (2022). Highly Protected Marine Areas (HPMAs). *GOV.UK*.
33. Watts, S. H. *et al.* (2022). Riding the elevator to extinction: Disjunct arctic-alpine plants of open habitats decline as their more competitive neighbours expand. *Biological Conservation*, 109620.
34. Ruiz-Navarro, A. *et al.* (2016). Predicting shifts in the climate space of freshwater fishes in Great Britain due to climate change. *Biological Conservation*, Vol 203, 33–42.
35. Vaughan, I. P. *et al.* (2012). Large-scale, long-term trends in British river macroinvertebrates. *Global Change Biology*, Vol 18, 2184–2194.
36. Orr, H. G. *et al.* (2015). What else do managers need to know about warming rivers? A United Kingdom perspective. *WIREs Water*, Vol 2, 55–64.
37. Hiddink, J. G. *et al.* (2015). Temperature tracking by North Sea benthic invertebrates in response to climate change. *Global Change Biology*, Vol 21, 117–129.
38. Lenoir, J. *et al.* (2020). Species better track climate warming in the oceans than on land. *Nat Ecol Evol*, Vol 4, 1044–1059.
39. Schippers, P. *et al.* (2021). Biodiversity conservation in climate change driven transient communities. *Biodivers Conserv*, Vol 30, 2885–2906.
40. Broughton, R. K. *et al.* (2022). The Red-billed Leiothrix (Leiothrix lutea): a new invasive species for Britain? *Ibis*, Vol n/a,
41. Thackeray, S. J. *et al.* (2010). Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments. *Global Change Biology*, Vol 16, 3304–3313.
42. Samplonius, J. M. *et al.* (2021). Strengthening the evidence base for temperature-mediated phenological asynchrony and its impacts. *Nat Ecol Evol*, Vol 5, 155–164. Nature Publishing Group.
43. Beaugrand, G. *et al.* (2008). Causes and projections of abrupt climate-driven ecosystem shifts in the North Atlantic. *Ecology Letters*, Vol 11, 1157–1168.
44. Reid, P. C. *et al.* (2016). Global impacts of the 1980s regime shift. *Global Change Biology*, Vol 22, 682–703.
45. Büntgen, U. *et al.* (2022). Plants in the UK flower a month earlier under recent warming. *Proc. R. Soc. B.*, Vol 289, 20212456.
46. Settele, J. *et al.* (2016). Climate change impacts on pollination. *Nature Plants*, Vol 2, 1–3.
47. Laizé, C. L. R. *et al.* (2014). Projected Flow Alteration and Ecological Risk for Pan-European Rivers. *River Research and Applications*, Vol 30, 299–314.
48. Tsavdaridou, A. I. *et al.* (2022). Novel climates in European river sub-basins pose a challenge for the persistence of freshwater fish. *Science of The Total Environment*, Vol 830, 154696.
49. Palmer, G. *et al.* (2017). Climate change, climatic variation and extreme biological responses. *Phil. Trans. R. Soc. B*, Vol 372, 20160144.

50. McDermott Long, O. *et al.* (2017). Sensitivity of UK butterflies to local climatic extremes: which life stages are most at risk? *J Anim Ecol*, Vol 86, 108–116.
51. Oliver, T. H. *et al.* (2013). Population resilience to an extreme drought is influenced by habitat area and fragmentation in the local landscape. *Ecography*, Vol 36, 579–586.
52. Oliver, T. H. *et al.* (2015). Interacting effects of climate change and habitat fragmentation on drought-sensitive butterflies. *Nature Clim Change*, Vol 5, 941–945. Nature Publishing Group.
53. Frölicher, T. L. *et al.* (2018). Marine heatwaves under global warming. *Nature*, Vol 560, 360–364. Nature Publishing Group.
54. Russel, T. *et al.* (2018). Climate change and marine conservation: Maerl Beds. 8. MCCIP.
55. Smedley, M. *et al.* (2018). Climate change and marine conservation: Horse Mussel Beds. 8. MCCIP.
56. Moore, P. J. *et al.* (2020). Impacts of climate change on shallow and shelf subtidal habitats, relevant to the coastal and marine environment around the UK. *MCCIP Science Review*, 272–292.
57. Burden, A. *et al.* (2020). Impacts of climate change on coastal habitats, relevant to the coastal and marine environment around the UK. *MCCIP Science Review 2020*, 28 pages. Marine Climate Change Impacts Partnership (MCCIP), Lowestoft, UK.
58. Oaten, J. *et al.* (2021). *Assessing the vulnerability of Annex I marine habitats to climate change in Wales*. Natural Resources Wales.
59. Galbraith, C. *et al.* (2022). Sites of Special Scientific Interest (SSSIs) in England: their historical development and prospects in a changing environment. Natural England.
60. Schmidt, D. N. *et al.* (2022). Marine protected areas in the context of climate change: key challenges for coastal social-ecological systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol 377, 20210131. Royal Society.
61. Hoppit, G. *et al.* (2022). Are marine protected areas an adaptation measure against climate change impacts on coastal ecosystems? A UK case study. *Nature-Based Solutions*, Vol 2, 100030.
62. JNCC (2021). UKBI - C1. Protected areas | JNCC - Adviser to Government on Nature Conservation.
63. Morecroft, M. D. *et al.* (2012). Resilience to climate change: translating principles into practice. *Journal of Applied Ecology*, Vol 49, 547–551.
64. Oliver, T. H. *et al.* (2015). Biodiversity and Resilience of Ecosystem Functions. *Trends in Ecology & Evolution*, Vol 30, 673–684.
65. Duffield, S. J. *et al.* (2021). Climate change vulnerability and the state of adaptation on England's National Nature Reserves. *Biological Conservation*, Vol 254, 108938.
66. Bowgen, K. M. *et al.* (2022). Conservation interventions can benefit species impacted by climate change. *Biological Conservation*, Vol 269, 109524.
67. Environmental Audit Committee (2022). Biodiversity in the UK: bloom or bust? 144.
68. Natural England and RSPB (2019). Climate Change Adaptation Manual - Evidence to support nature conservation in a changing climate. Natural England.
69. Ausden, M. (2014). Climate Change Adaptation: Putting Principles into Practice. *Environmental Management*, Vol 54, 685–698.
70. Williams, B. K. *et al.* (2013). Confronting dynamics and uncertainty in optimal decision making for conservation. *Environ. Res. Lett.*, Vol 8, 025004.
71. Morecroft, M. D. *et al.* (2019). Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems. *Science*, Vol 366, eaaw9256.
72. Aplet, G. *et al.* (2010). The trouble with naturalness: Rethinking park and wilderness goals. in *Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change*. (eds. Cole, D. et al.) 12–29. Island Press.
73. Thompson, L. M. *et al.* (2021). Responding to Ecosystem Transformation: Resist, Accept, or Direct? *Fisheries*, Vol 46, 8–21.
74. Schuurman, G. W. *et al.* (2022). Navigating Ecological Transformation: Resist–Accept–Direct as a Path to a New Resource Management Paradigm. *BioScience*, Vol 72, 16–29.
75. Duffield, S. (2022). Personal Communication.
76. The Wildlife Trusts (2022). Changing nature: A climate adaptation report by The Wildlife Trusts. The Wildlife Trusts.
77. Haasnoot, M. *et al.* (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, Vol 23, 485–498.
78. WSP, Risk Solutions and ADAS (2020). Interacting risks in frastructure and the built and natural environments. Committee on Climate Change.
79. Thomas, C. D. *et al.* (2012). Protected areas facilitate species' range expansions. *Proc. Natl. Acad. Sci. U.S.A.*, Vol 109, 14063–14068.
80. Sanderson, F. J. *et al.* (2016). Assessing the Performance of EU Nature Legislation in Protecting Target Bird Species in an Era of Climate Change. *Conservation Letters*, Vol 9, 172–180.
81. Natural England (2022). Sites of special scientific interest: managing your land. *GOV.UK*.
82. Starnes, T. *et al.* (2021). The extent and effectiveness of protected areas in the UK. *Global Ecology and Conservation*, Vol 30, e01745.
83. Mosedale, J. *et al.* (2022). A think piece on the effectiveness of protected areas in England. Natural England.
84. Oliver, T. H. *et al.* (2012). A decision framework for considering climate change adaptation in biodiversity conservation planning. *Journal of Applied Ecology*, Vol 49, 1247–1255.
85. O'Leary, B. C. *et al.* (2020). Options for managing human threats to high seas biodiversity. *Ocean & Coastal Management*, Vol 187, 105110.
86. Sheehan, E. V. *et al.* (2021). Rewilding of Protected Areas Enhances Resilience of Marine Ecosystems to Extreme Climatic Events. *Frontiers in Marine Science*, Vol 8,
87. Chaniotis, P. *et al.* (2018). Developing an ecologically-coherent and well-managed Marine Protected Area network in the United Kingdom: 10 years of reflection from the Joint Nature Conservation Committee. *Biodiversity*, 1–8.
88. Marine Conservation Society (2020). MPA Reality Check.
89. Macgregor, N. A. *et al.* (2014). Adaptation in Practice: How Managers of Nature Conservation Areas in Eastern England are Responding to Climate Change. *Environmental Management*, Vol 54, 700–719.
90. Oliver, T. H. *et al.* (2016). Are existing biodiversity conservation strategies appropriate in a changing climate? *Biological Conservation*, Vol 193, 17–26.
91. Thomas, C. *et al.* (2022). Facilitating dynamic and inclusive biodiversity conservation in Britain: An Anthropocene perspective. Natural England Research Report NECR413.
92. Peterson St-Laurent, G. *et al.* (2021). R–R–T (resistance–resilience–transformation) typology reveals differential conservation approaches across ecosystems and time. *Communications Biology*, Vol 4, 1–9.

93. JNCC Calcium-rich nutrient-poor lakes, lochs and pools (Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.) - Special Areas of Conservation.
94. Holman, I. *et al.* (2009). *Understanding the effects of coming environmental change on Bosherston Lakes as a basis for a sustainable conservation management strategy.* Countryside Council for Wales.
95. Ulster Wildlife, RSPB NI, National Trust NI and Woodland Trust (2021). Nature Recovery Networks for Northern Ireland. Northern Ireland Landscape Partnership.
96. Elliott, J. *et al.* (2022). Land of opportunity: a new land use framework to restore nature and level up Britain. Green Alliance.
97. Keppel, G. *et al.* (2012). Refugia: identifying and understanding safe havens for biodiversity under climate change. *Global Ecology and Biogeography*, Vol 21, 393–404.
98. Maclean, I. M. D. *et al.* (2015). Microclimates buffer the responses of plant communities to climate change. *Global Ecology and Biogeography*, Vol 24, 1340–1350.
99. Prosser, C. D. *et al.* (2010). Conserving Geodiversity Sites in a Changing Climate: Management Challenges and Responses. *Geoheritage*, Vol 2, 123–136.
100. Thomas, J. A. *et al.* (2011). Evidence based conservation of butterflies. *J Insect Conserv*, Vol 15, 241–258.
101. Suggitt, A. J. *et al.* (2015). Microclimate affects landscape level persistence in the British Lepidoptera. *J Insect Conserv*, Vol 19, 237–253.
102. Suggitt, A. J. *et al.* (2018). Extinction risk from climate change is reduced by microclimatic buffering. *Nature Clim Change*, Vol 8, 713–717. Nature Publishing Group.
103. Wildlife Trust BCN Banking on Butterflies project.
104. Newbold, T. *et al.* (2018). Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide. *PLOS Biology*, Vol 16, e2006841. Public Library of Science.
105. Newbold, T. *et al.* (2019). Climate and land-use change homogenise terrestrial biodiversity, with consequences for ecosystem functioning and human well-being. *Emerging Topics in Life Sciences*, Vol 3, 207–219.
106. Bailey, J. J. *et al.* (2018). Models of upland species' distributions are improved by accounting for geodiversity. *Landscape Ecol*, Vol 33, 2071–2087.
107. Massimino, D. *et al.* (2020). Can microclimate offer refuge to an upland bird species under climate change? *Landscape Ecol*, Vol 35, 1907–1922.
108. The Woodland Trust (2016). Keeping Rivers Cool: A Guidance Manual Creating riparian shade for climate change adaptation. 15.
109. Wilby, R. L. *et al.* (2010). Evidence needed to manage freshwater ecosystems in a changing climate: Turning adaptation principles into practice. *Science of The Total Environment*, Vol 408, 4150–4164.
110. Johnson, M. F. *et al.* (2015). Seeing the landscape for the trees: Metrics to guide riparian shade management in river catchments. *Water Resources Research*, Vol 51, 3754–3769.
111. Brito-Morales, I. *et al.* (2022). Towards climate-smart, three-dimensional protected areas for biodiversity conservation in the high seas. *Nat. Clim. Chang.*, Vol 12, 402–407.
112. Gillingham, P. K. *et al.* (2015). The effectiveness of protected areas in the conservation of species with changing geographical ranges. *Biological Journal of the Linnean Society*, Vol 115, 707–717.
113. Gillingham, P. K. *et al.* (2015). High Abundances of Species in Protected Areas in Parts of their Geographic Distributions Colonized during a Recent Period of Climatic Change. *Conservation Letters*, Vol 8, 97–106.
114. Hiley, J. R. *et al.* (2013). Protected areas act as establishment centres for species colonizing the UK. *Proceedings of the Royal Society B: Biological Sciences*, Vol 280, 20122310. Royal Society.
115. Johnston, A. *et al.* (2013). Observed and predicted effects of climate change on species abundance in protected areas. *Nature Clim Change*, Vol 3, 1055–1061. Nature Publishing Group.
116. Hooftman, D. A. P. *et al.* (2016). Reductions in connectivity and habitat quality drive local extinctions in a plant diversity hotspot. *Ecography*, Vol 39, 583–592.
117. Hodgson, J. A. *et al.* (2011). Habitat re-creation strategies for promoting adaptation of species to climate change. *Conservation Letters*, Vol 4, 289–297.
118. Wallis, D. W. *et al.* (2015). Condatis; software to assist with the planning of habitat restoration v0.6.0. Zenodo.
119. Isaac, N. J. B. *et al.* (2018). Defining and delivering resilient ecological networks: Nature conservation in England. *Journal of Applied Ecology*, Vol 55, 2537–2543.
120. CPRE (2021). Our hedgerow campaign: helping people and nature tackle the climate crisis. *CPRE*.
121. Haasnoot, M. *et al.* (2011). A method to develop sustainable water management strategies for an uncertain future. *Sustainable Development*, Vol 19, 369–381.
122. Hall, J. W. *et al.* (2019). Adaptation thresholds and pathways for tidal flood risk management in London. *Climate Risk Management*, Vol 24, 42–58.
123. Krisht, S. *et al.* (2018). Research to Assess the Economics of Coastal Change Management in England and to Determine Potential Pathways for a Sample of Exposed Communities. Jacobs.
124. Committee on Climate Change (2018). Managing the coast in a changing climate. Committee on Climate Change.
125. Somserset Wildlife Trust (2021). Adapting The Levels.
126. NatureScot *et al.* (2016). Enhance opportunities for species to disperse - Montane willows.
127. Sayer, C. D. (2014). Conservation of aquatic landscapes: ponds, lakes, and rivers as integrated systems. *WIREs Water*, Vol 1, 573–585.
128. Travers, T. J. P. *et al.* (2021). Habitat patches providing south–north connectivity are under-protected in a fragmented landscape. *Proceedings of the Royal Society B: Biological Sciences*, Vol 288, 20211010. Royal Society.
129. Addy, S. *et al.* (2016). River Restoration and Biodiversity: Nature-Based Solutions for Restoring the Rivers of the UK and Republic of Ireland. IUCN.
130. Grill, G. *et al.* (2019). Mapping the world's free-flowing rivers. *Nature*, Vol 569, 215–221.
131. Thieme, M. L. *et al.* (2020). Dams and protected areas: Quantifying the spatial and temporal extent of global dam construction within protected areas. *Conservation Letters*, Vol 13, e12719.
132. O'Shaughnessy, E. *et al.* (2016). Conservation Leverage: Ecological Design Culverts also Return Fiscal Benefits. *Fisheries*, Vol 41, 750–757.
133. Environment Agency River Obstacles.
134. Thames Rivers Trust (2022). ObstacEELS. *ObstacEELS*.
135. Januchowski-Hartley, S. R. *et al.* (2022). Supporting proactive planning for climate change adaptation and conservation using an attributed road-river structure dataset. *Journal of Environmental Management*, Vol 321, 115959.
136. Clerkin, S. (2020). Working cross-border in nature conservation with regard to different designations,

structures and management. *The Journal of Cross Border Studies in Ireland*, Vol 15, 12.
137. Northern Ireland Environment Link and Environmental Pillar Joint Briefing: Brexit and cross-border environmental cooperation on the island of Ireland.
138. Natural England (2021). Natural England's climate change risk assessment and adaptation plan. Natural England.
139. Balbar, A. C. *et al.* (2019). The current application of ecological connectivity in the design of marine protected areas. *Global Ecology and Conservation*, Vol 17, e00569.
140. SMMR (2021). Marine Spatial Planning Addressing Climate Effects (MSPACE) - Sustainable Management of Marine Resources.
141. Pearce-Higgins, J. W. (2011). Modelling conservation management options for a southern range-margin population of Golden Plover Pluvialis apricaria vulnerable to climate change. *Ibis*, Vol 153, 345–356.
142. Pearce-Higgins, J. W. *et al.* (2019). Site-based adaptation reduces the negative effects of weather upon a southern range margin Welsh black grouse Tetrao tetrix population that is vulnerable to climate change. *Climatic Change*, Vol 153, 253–265.
143. Wildlife and Countryside Link (2022). Response to Consultation on Nature Recovery Green Paper. Wildlife and Countryside Link.
144. Wotton, S. *et al.* (2009). Boom or bust – a sustainable future for reedbeds and Bitterns? *British Wildlife*, Vol 20, 11.
145. RSPB (2021). Britain's loudest bird makes roaring recovery.
146. Harris, J. A. *et al.* (2006). Ecological Restoration and Global Climate Change. *Restoration Ecology*, Vol 14, 170–176.
147. du Toit, J. T. *et al.* (2019). The differences between rewilding and restoring an ecologically degraded landscape. *Journal of Applied Ecology*, Vol 56, 2467–2471.
148. Bullock, J. M. *et al.* (2022). Future restoration should enhance ecological complexity and emergent properties at multiple scales. *Ecography*, Vol 2022,
149. Hodgson, J. A. *et al.* (2011). Habitat area, quality and connectivity: striking the balance for efficient conservation. *Journal of Applied Ecology*, Vol 48, 148–152.
150. Field, R. H. *et al.* (2020). The value of habitats of conservation importance to climate change mitigation in the UK. *Biological Conservation*, Vol 248, 108619.
151. Stafford, R. *et al.* (2021). Nature-based solutions for climate change in the UK: A report by the British Ecological Society. British Ecological Society.
152. Seddon, N. (2022). Harnessing the potential of nature-based solutions for mitigating and adapting to climate change. *Science*, Vol 376, 1410–1416.
153. Williams, C. *et al.* (2022). Rewilding the Sea? A Rapid, Low Cost Model for Valuing the Ecosystem Service Benefits of Kelp Forest Recovery Based on Existing Valuations and Benefit Transfers. *Frontiers in Ecology and Evolution*, Vol 10,
154. Scottish Water (2020). Biodiversity Report 2020: Contributing to Scotland's Six Big Steps for Nature. Scottish Water.
155. Water Resources East (2022). The Water Resources East Natural Capital Plan. Water Resources East.
156. Brazier, R. *et al.* *River Otter Beaver Trial: Science and Evidence Report.* 132. Devon Wildlife Trust.
157. Future Generations Commissioner for Wales (2020). The Future Generations Report 2020: Executive Summaries - A Resilient Wales. Future Generations Commissioner for Wales.
158. Jones, L. *et al.* (2020). Climate driven thresholds in the natural environment.
159. Thompson, J. R. *et al.* (2009). Modelling the hydrological impacts of climate change on UK lowland wet grassland. *Wetlands Ecol Manage*, Vol 17, 503–523.
160. Thompson, J. R. *et al.* (2017). Simulation of the hydrological impacts of climate change on a restored floodplain. *Hydrological Sciences Journal*, Vol 62, 2482–2510. Taylor & Francis.
161. Herrera-Pantoja, M. *et al.* (2012). The potential impact of climate change on groundwater-fed wetlands in eastern England. *Ecohydrology*, Vol 5, 401–413.
162. Forest Research (2020). Managing England's woodlands in a climate emergency. Forest Research.
163. Ovenden, T. S. *et al.* (2022). Intimate mixtures of Scots pine and Sitka spruce do not increase resilience to spring drought. *Forest Ecology and Management*, Vol 521, 120448.
164. Buechel, M. *et al.* (2022). Hydrological impact of widespread afforestation in Great Britain using a large ensemble of modelled scenarios. *Commun Earth Environ*, Vol 3, 6.
165. Cavin, L. *et al.* (2017). Highest drought sensitivity and lowest resistance to growth suppression are found in the range core of the tree Fagus sylvatica L. not the equatorial range edge. *Glob Change Biol*, Vol 23, 362–379.
166. Science and Technology Select Committee (2022). *Nature-based solutions: rhetoric or reality? - The potential contribution of nature-based solutions to net zero in the UK*. 82. House of Lords.
167. Pearce-Higgins, J. (2021). Climate change and UK's birds. British Trust for Ornithology.
168. IUCN/SSC (2013). Guidelines for Reintroductions and Other Conservation Translocations. 57. IUCN Species Survival Commission.
169. Minter, M. *et al.* (2020). Past, current, and potential future distributions of unique genetic diversity in a cold-adapted mountain butterfly. *Ecology and Evolution*, Vol 10, 11155–11168.
170. NatureScot (2015). Considering Translocation - Creag Meagaidh.
171. The IUCN Red List of Threatened Species. *IUCN Red List of Threatened Species*.
172. Thomas, C. D. (2011). Translocation of species, climate change, and the end of trying to recreate past ecological communities. *Trends in Ecology & Evolution*, Vol 26, 216–221.
173. Maxwell, S. L. *et al.* (2020). Area-based conservation in the twenty-first century. *Nature*, Vol 586, 217–227.
174. IUCN WCPA Task Force on OECMs (2019). Recognising and reporting other effective area-based conservation measures. IUCN, International Union for Conservation of Nature.
175. UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) *et al.* (2021). Assess the potential of other effective area-based conservation measures as a driver for landscape-level conservation and connectivity in the EU. UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), the Institute for European Environment Policy (IEEP), and Trinomics.
176. Oliver, T. H. *et al.* (2015). Declining resilience of ecosystem functions under biodiversity loss. *Nat Commun*, Vol 6, 10122. Nature Publishing Group.
177. Brennan, A. *et al.* (2022). Functional connectivity of the world's protected areas. *Science*, Vol 376, 1101–1104.
178. Lunt, I. D. *et al.* (2013). Using assisted colonisation to conserve biodiversity and restore ecosystem function under climate change. *Biological Conservation*, Vol 157, 172–177.
179. Falcón, W. *et al.* (2018). Island rewilding with giant tortoises in an era of climate change. *Philosophical*

Transactions of the Royal Society B: Biological Sciences, Vol 373, 20170442. Royal Society.
180. Ennos, R. *et al.* (2019). Is the introduction of novel exotic forest tree species a rational response to rapid environmental change? – A British perspective. *Forest Ecology and Management*, Vol 432, 718–728.
181. Minteer, B. A. *et al.* (2010). Move it or lose it? The ecological ethics of relocating species under climate change. *Ecological Applications*, Vol 20, 1801–1804.
182. NatureScot Scottish Code for Conservation Translocations | NatureScot.
183. Defra and Natural England Species reintroductions and other conservation translocations. *GOV.UK*.
184. Pearce-Higgins, J. W. *et al.* (2022). A framework for climate change adaptation indicators for the natural environment. *Ecological Indicators*, Vol 136, 108690.
185. Mancini, F. *et al.* (2022). Co-designing an Indicator of Habitat Connectivity for England. *Front. Ecol. Evol.*, Vol 10, 892987.
186. Jellesmark, S. *et al.* (2021). A counterfactual approach to measure the impact of wet grassland conservation on U.K. breeding bird populations. *Conservation Biology*, Vol 35, 1575–1585.
187. Watts, K. *et al.* (2020). Ecological time lags and the journey towards conservation success. *Nat Ecol Evol*, Vol 4, 304–311.
188. Jellesmark, S. *et al.* (2022). The effect of conservation interventions on the abundance of breeding waders within nature reserves in the United Kingdom. *Ibis*, Vol n/a,
189. RSPB (2020). A Lost Decade for Nature 2020.
190. Cunningham, C. A. *et al.* (2021). The effectiveness of the protected area network of Great Britain. *Biological Conservation*, Vol 257, 109146.
191. Buckland, S. T. *et al.* (2017). Monitoring the biodiversity of regions: Key principles and possible pitfalls. *Biological Conservation*, Vol 214, 23–34.
192. Duffus, N. E. *et al.* (2022). Current conservation policies in the UK and Ireland overlook endangered insects and are taxonomically biased towards Lepidoptera. *Biological Conservation*, Vol 266, 109464.
193. Martin, J. *et al.* (2022). The Landscape of Landscape Monitoring. 9. University of Plymouth.
194. Hoppit, G. *et al.* (2022). A Regional View of the Response to Climate Change: A Meta-Analysis of European Benthic Organisms' Responses. *Frontiers in Marine Science*, Vol 9,
195. Pettorelli, N. *et al.* (2019). Anticipating arrival: Tackling the national challenges associated with the redistribution of biodiversity driven by climate change. *Journal of Applied Ecology*, Vol 56, 2298–2304.
196. Borgelt, J. *et al.* (2022). More than half of data deficient species predicted to be threatened by extinction. *Commun Biol*, Vol 5, 1–9. Nature Publishing Group.
197. Botanic Gardens Conservation International International Plant Sentinel Network. *Botanic Gardens Conservation International*.