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PERSPECTIVE

Revisiting the case for assisted colonisation under rapid climate change

Charlie J. Gardner[1] | James M. Bullock[2]

[1]Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, UK

[2]UK Centre for Ecology and Hydrology, Wallingford, UK

Correspondence
James M. Bullock
Email: jmbul@ceh.ac.uk

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Abstract

1. Climate change is driving the rapid reorganisation of the world's biota as species shift their ranges to track suitable conditions, but habitat fragmentation and other barriers hinder this adaptive response for species with limited dispersal ability. Active translocation into newly suitable areas has been suggested as a strategy to conserve species otherwise unable to expand their ranges; however, assisted colonisation has not been widely adopted because the deliberate introduction of non-native species poses invasion risks and runs counter to traditional conservation approaches.
2. We use the future of forest ecosystems in Great Britain as a thought experiment to argue that mass-scale assisted colonisation will likely be required not to conserve threatened species, but to maintain functional ecosystems. As the climate changes, existing forest plant and animal communities of northern Europe will increasingly die out in their current locations, but in Great Britain, their replacement with range-expanding species from further south will be limited to a subset of mobile species able to overcome the ocean barrier. As a result, British forests will come to lack many important component species unless these are actively translocated; will have reduced resilience and adaptive capacity; and may eventually collapse.
3. *Policy implications*: Maintaining functioning ecosystems in a hotter world will require mass-scale assisted colonisation, so appropriate conservation policy, legislative frameworks and regulating bodies must be urgently developed. Conservationists must shift focus from the prevention of species extinctions to the maintenance of functioning ecosystems; from trying to prevent change and maintain the biotic communities, we have to trying to shape the biotic changes that are now inevitable. We must shift from reactive to proactive approaches to facilitate the emergence of robust novel ecosystems.

KEYWORDS
adaptation, assisted migration, ecosystem function, ecosystem services, forest, novel ecosystems, range shift, translocation

1 | INTRODUCTION

Climate change, in the decade to 2023, increased European land temperatures by an average of 2.12 to 2.19°C from the beginning of the industrial revolution, changing the local conditions to which all species are adapted (European Environment Agency, 2024). While some species may be able to adapt within their current ranges (Alberto et al., 2013), such adaptive responses will often be insufficient (Radchuk et al., 2019), and many species have been shifting their ranges to track shifting niche space. Typically, such movements are towards the poles and to higher altitudes (Chen et al., 2011), though local climate variation, land use change, and other factors result in variation in the direction of movement (Rubenstein et al., 2023), and buffering by forest canopies may slow initial responses (De Frenne et al., 2021). For many species, the pace of range expansion is insufficient to keep up with the pace of climate change (Ash et al., 2017; Román-Palacios & Wiens, 2020), while others are prevented from shifting ranges by geographical and, in particular, anthropogenic barriers caused by the clearance and fragmentation of habitats (Marjakangas et al., 2023; Platts et al., 2019). As a result, many populations and species face a high risk of extinction this century (Román-Palacios & Wiens, 2020), even before cascading extinctions are considered (Strona & Bradshaw, 2022).

In response, conservationists have proposed a strategy of assisted colonisation (or assisted migration), whereby species are purposefully translocated beyond their current ranges to areas identified as future refugia, but to which they are unable to disperse of their own accord. First discussed in the literature at least 40 years ago (Peters & Darling, 1985), the concept has attracted debate and criticism arising from a range of concerns, including ethics, feasibility, perceived sociopolitical barriers and, in particular, the risk of unintended biological invasions (Ricciardi & Simberloff, 2009). This is perhaps unsurprising given the long history of negative biodiversity impacts arising from species introductions indeed, alien invasive species were identified as one of the 'four horsemen of the ecological apocalypse' during the field's early days as a discipline (Diamond, 1984) and remain a major driver of biodiversity loss (Roy et al., 2023). As such, the approach was said to '[fly] in the face of conventional conservation approaches' (Hoegh-Guldberg et al., 2008).

Despite rapid growth in our understanding of climate change impacts on biodiversity, research on assisted colonisation peaked in 2015 and has declined since, while most recent research has been carried out in forestry science rather than conservation (Benomar et al., 2022)—likely because of the economic importance of commercial forestry in many countries. But while research fashions have moved on in the constant quest for novelty, existing research has not served to stimulate much movement in the real world of biodiversity policy and management: little assisted colonisation has been carried out in practice (Butt et al., 2021; Twardek et al., 2023), and there appears to be little recognition of its likely importance in the face of current and future climate changes. For example, neither the British Ecological Society's (BES) 2021 review of nature-based solutions in the UK (Stafford et al., 2021) nor its recent research agenda for future ecological research (Malhi et al., 2023) mentions assisted colonisation, and we can find no reference in the *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES, 2019). Despite a high-profile call for a global policy on assisted colonisation in 2021 (Brodie et al., 2021), it is not mentioned in the 2022 Global Biodiversity Framework of the Convention on Biological Diversity (CBD, 2022).

Assisted colonisation has typically been framed by conservationists as an approach for conserving threatened species as climate change contracts their ranges (Brodie et al., 2021; Butt et al., 2021). However, it could also be carried out to maintain or restore ecological function: in other words, the objective of a translocation could be to benefit the recipient ecosystem, not the translocated species. This idea was discussed a decade ago (Lunt et al., 2013); however, it has been largely ignored in the literature since (Benomar et al., 2022; Twardek et al., 2023). For example, Benomar et al. (2022) identified 71 prominent keywords frequently used in assisted colonisation-focused publications, but these did not include the terms 'ecosystem' or 'function'. Here, we revisit the case made by Lunt et al. (2013) and argue that, given the rapidity of climate change and the extent of habitat fragmentation through most terrestrial ecosystems, mass-scale assisted colonisation is likely to be required to maintain ecosystem functioning into the future. Specifically, we suggest the maintenance of the functioning ecosystems on which most biodiversity depends—rather than the prevention of species extinctions—provides the strongest rationale for assisted colonisation in a rapidly reorganising world. We illustrate our argument with a thought experiment considering the future of forest ecosystems in Great Britain, where the isolated nature of the system makes the difficulties of rapid ecosystem adaptation easier to conceptualise.

2 | EUROPE'S SHIFTING BIOTA

At the peak of the Last Glacial Period 18,000 years ago, Scandinavia and the northern parts of what would become the British Isles were covered in ice; what is now southern England and the rest of northern and central Europe were tundra; and permafrost extended almost as far as the Mediterranean (Hewitt, 1999). As the climate warmed and the ice retreated, communities of plants and animals shifted northwards in response (Giesecke et al., 2017; Hewitt, 1999), expanding at the leading edge of their ranges through colonisation, and retreating at the trailing edge as populations became extinct. Great Britain was at the time the northwestern peninsula of Europe, connected to the mainland via the Doggerland land bridge, which permitted its colonisation by species unable to fly. However, rising sea levels submerged the land bridge by about 9000 years ago (Walker et al., 2020), preventing further colonisation by species with poor dispersal. While some terrestrial or freshwater species in Britain may have expanded from refugia within glaciated regions (Stewart & Lister, 2001), the vast majority either (i) colonised over land in

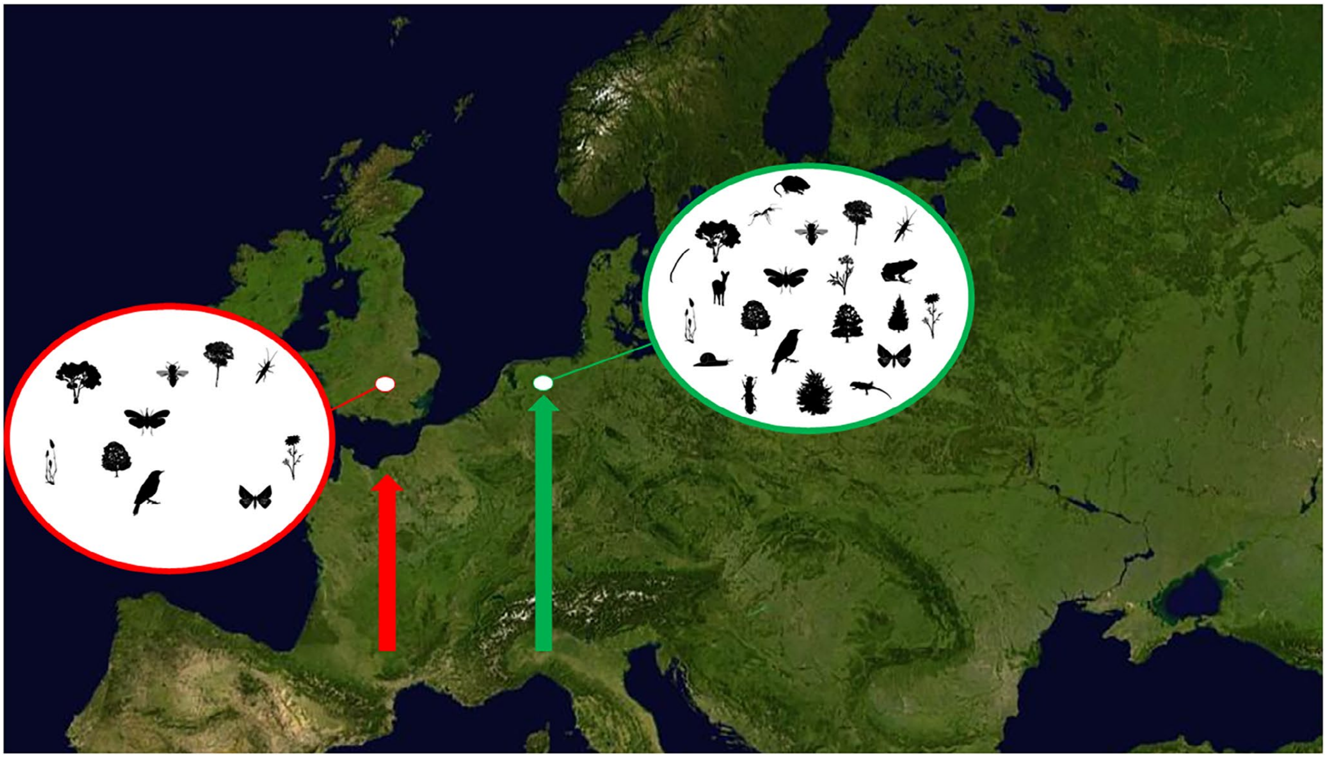

FIGURE 1 Map of Europe showing illustrative future composition of forest communities. In the absence of assisted colonisation, communities in British forests (left circle) will be impoverished compared with those on mainland Europe (right circle) because the English Channel will prevent range expansion for species with limited dispersal abilities.

the brief window between the retreat of the tundra and the rising of the seas, (ii) were subsequently introduced by humans or (iii) subsequently colonised across the sea independently.

The subsequent Holocene has been a time of remarkable climatic stability, but European species are now shifting their ranges again in response to contemporary climate change (Hällfors et al., 2024; Howard et al., 2023). Europe's forests are 'undergoing a profound reorganisation' (Wessely et al., 2024), and with 3.2°C of global heating expected within the century (IPCC, 2023), this trend is likely to accelerate. By 2050 London is expected to experience a climate similar to that currently experienced in Barcelona (Bastin et al., 2019), and the north-west of Europe will become increasingly unsuitable for the tree (and other) species which currently dominate its forests (Mauri et al., 2022, 2023; Wessely et al., 2024).

As plant and animal communities shift northwards through Europe, they will reach the English Channel or North Sea. To highly vagile species such as birds, many flying invertebrates, and plants with wind- or bird-dispersed seeds, this will pose only a partial barrier: many will likely successfully expand into Britain, and they may be accepted as natural colonisers. This is already occurring; several bird and invertebrate species have recently colonised Britain, and they are generally considered welcome additions to the fauna (Cranston et al., 2022). However, for the majority of non-flying species, including terrestrial mammals, reptiles, amphibians, non-volant arthropods, the invertebrate and fungal communities of leaf litter and soil, freshwater species, and plants that are dispersed by neither birds nor the wind, the ocean will present a near-insurmountable barrier, and they will be unable to colonise (since transoceanic dispersal by rafting, which does rarely occur, De Queiroz, 2014, is not a significant force over decadal timescales). As a result, the future forest communities of southern Great Britain will be highly impoverished compared with equivalent mainland areas at the same latitude because many *natural components* of these expanding ecosystems will be missing (Figure 1).

3 | FROM REACTIVE TO PROACTIVE CONSERVATION

This thought experiment highlights an emerging yet urgent conundrum for conservationists and land managers in Britain. Prevailing conservation philosophies, policy and legal frameworks counsel against the introduction of non-native species, since translocated species risk becoming invasive and causing negative ecological or economic impacts. While the reintroduction of extinct species may be lawful under the Wildlife and Countryside Act 1981, the introduction of any animal 'not normally resident' in Great Britain is an offence. Separate guidance exists for overseas translocations into England and Scotland (DEFRA, 2024; NSRF, 2014), but practice in the UK has been confined to reintroductions (Wells & Heydon, 2022). While there is a taskforce for England whose 'objective is to realise the full benefits of species conservation translocations for nature recovery and society' and which has discussed assisted colonisation, its name ('Species Reintroductions Taskforce') implies a focus on extinct natives (Government of UK, 2024).

While existing guidance distinguishes between native and non-native species, Lemoine and Svenning (2022) make a compelling argument that the concept of ecological nativeness is not binary and not all non-natives should be considered as equally 'alien'. Assisted colonisation would likely not involve the translocation of species from unrelated biotas on distant landmasses, which can pose a high invasion risk (Mueller & Hellmann, 2008), but only species from the ecosystems whose adaptation we are trying to facilitate, that is 'near natives'. With similar geographies and ecologies to resident species, near natives could integrate well into existing ecosystems and together should form functioning ecosystems well adapted to future climate states without causing damaging invasions.

Both IUCN guidelines on conservation translocations (IUCN, 2013) and assisted colonisation decision frameworks (Hoegh-Guldberg et al., 2008) state that it should only be carried out if the candidate species for translocation are threatened with declines from climate change. This would suggest that the introduction of common European species to Britain is not required if they are able to maintain populations on the mainland. However, in the absence of assisted colonisation, the forests of southern Great Britain may suffer rapid impoverishment as the species that currently live there die out: if they are not replaced by analogous species better suited to emerging conditions, the ecosystem could collapse, leaving the region with highly degraded forests.

Forests are more than just populations of trees and habitats for other species—they are complex ecosystems whose function depends on the interactions between their constituent species, and they provide irreplaceable ecosystem services. Regardless of whether British forests can contribute to the rescue of Europe's threatened biota, conservationists, land managers, and the public will want southern Britain to retain forests in the future because they provide habitat for myriad species, store carbon, help prevent flooding and carry amenity value for the people who use and love them. If our objective was purely to conserve species, then the translocation of mainland species to Britain may be seen as unnecessary, but that may no longer be an appropriate goal. What we should be striving for in a time of rapid change is the maintenance of functional, resilient, adaptable ecosystems that generate the ecosystem services we need to help avoid the worst of climate change and cope with its impacts (Gardner & Bullock, 2021). This requires us to shift from trying to conserve species to instead trying to conserve ecosystem function because this is what will allow us to maintain the planetary conditions that allow biodiversity to thrive.

This, in turn, requires us to shift from a reactive to a proactive approach to maintaining biodiversity in a time of rapid change. Rather than looking to the past and trying to maintain historic patterns of 'native' biodiversity, which is an impossible goal in a changing climate, we should instead look to the future, ask ourselves what biodiversity we will need and want in a changed world, and take whatever active steps are necessary to facilitate the movement of species and adaptation of ecosystems to emerging conditions. In the case of forests in southern Britain, this will mean not only translocating trees, but also the fungal and invertebrate communities that allow trees to flourish, and the other plant and animal species that make up the ecosystem. In addition to translocating species beyond their current ranges, we will likely also need to carry out within-range 'assisted gene flow' for species whose current ranges span both Britain and southern Europe, such as the English oak (*Quercus robur*), because the genetic material required for survival in Mediterranean climates may not be found within British populations. Such movement of genetic material would need to be done carefully—and requires some research—to avoid negative outcomes such as through outbreeding depression or phenological mismatches.

Great Britain provides an illustrative example because the ocean barrier is easy to conceptualise, and islands in general are considered to be particularly threatened by climate change (Russell & Kueffer, 2019), partially due to dispersal barriers (Harter et al., 2015). But in reality, natural habitats are so fragmented across most of the world that many continental areas are effectively archipelagos of habitat islands within a matrix of agricultural land, roads, urban and other open areas of varying impenetrability (Riitters et al., 2016). If, therefore, we conclude that broad-scale assisted colonisation will be required to maintain forests in southern Britain, and then, it may equally be so for other ecosystems across continental areas.

Assisted colonisation is a growing area of research in forestry (Benomar et al., 2022), and its potential to help maintain timber productivity and other ecosystem services has been well modelled (Benito-Garzón & Fernández-Manjarrés, 2015; Duveneck & Scheller, 2015; Mauri et al., 2022). But while silviculturists, horticulturalists and agriculturalists routinely introduce species and varieties suited to emerging conditions, interest in assisted colonisation by conservationists has stagnated and waned (Benomar et al., 2022) even as climate impacts on biodiversity become ever more apparent.

Assisted colonisation will be challenging and complex, and unforeseen consequences will emerge. For example, tree species from warmer and drier climates will exhibit different functional attributes and may thus change the functioning of recipient ecosystems (Michalet et al., 2024). However, it is important to also acknowledge that climate change itself will change the functioning of forest ecosystems, potentially leading to their collapse. British forest ecosystems will not function in the future as they do now due to changes that are unavoidable: assisted colonisation, with the potential selection of species, can at least allow management of the trajectory of functional changes.

Half the planet is expected to be covered by novel ecosystems within the century (Ordonez et al., 2024). However, given the lack of ecological connectivity and the time lags involved in dispersal, they will be composed of only a high-mobility subset of species if they are left to reassemble without help. To maximise the diversity, resilience and adaptability of future ecosystems, we will need to actively translocate species and communities unable to disperse on their own. We will require mass-scale assisted colonisation.

4 | SPECIES SELECTION

The conventional approach to facilitate range shifts is the (re)establishment of habitat connectivity through corridors. At its simplest, assisted colonisation could be considered a 'virtual bridge', a replacement for corridors where these cannot be established. This approach would be essentially non-selective, as all species naturally reaching any dispersal barrier would, by default, be considered candidate species for translocation across it. However, the approach could also be carried out selectively, as it is when the aim is to save species threatened by climate change in their native ranges (Brodie et al., 2021; Butt et al., 2021). Choosing species to create or maintain well-functioning ecosystems raises different issues related to the increasing interest in framing conservation targets around ecosystem processes rather than species per se (Bullock et al., 2022). One approach would be to match functions, via species' traits, to desired tolerances to climatic changes; for example, drought tolerance (Bussotti et al., 2015; Quetin et al., 2023). It is likely to be more rewarding to use existing ecosystems in climates similar to projected future British climates as locations for choosing a range of species that could form the basis of similar ecosystems in Great Britain. These would be 'near-native', as discussed above, and by those criteria would not need trait matching to climate. Rather, the location and co-occurrence of these species would give a good template for future ecosystems in Great Britain, as they are adapted to the future climate and are known to interact to form ecosystems. Choosing exactly which species would be on the basis of developing interaction webs that are structurally complex and match, in form rather than composition, existing desired states for forest ecosystems (Tierney et al., 2009). The principle of adaptive management could apply here, as is promoted for ecosystem restoration (Maes et al., 2024), whereby functions are monitored, and new species are introduced, or other management actions trialled if the new ecosystems are not establishing well. Ultimately, this approach will be experimental, presenting an opportunity for scientists to collaborate closely with practitioners to develop ecosystems for the future.

5 | CONCLUSIONS

Although conservation has, through its short history, principally been focused on maintaining biodiversity by preventing species extinctions, climate change threatens not just species but entire ecosystems. Since human societies, economies and all other species depend on the maintenance of functional ecosystems, this calls for a shift in conservation priorities. We must conserve the game, not the players, maintaining ecological and evolutionary processes rather than particular species: that requires us to stop trying to maintain the world as it was and instead try to shape the world that will be (Gardner & Bullock, 2021). To maximise our chances of retaining functioning ecosystems in future, we must facilitate biodiversity responses to climate change by helping species and communities overcome existing and novel anthropogenic barriers. This will require the urgent development of conservation policy, legislative frameworks and regulatory bodies at the appropriate scales, as well as the research required to ensure these operate from a solid evidence base.

To paraphrase the proverb, the best time to plan and facilitate the establishment of the climate-resilient ecosystems of tomorrow was 30 years ago, but the next best time is now.

AUTHOR CONTRIBUTIONS

Charlie J. Gardner and James M. Bullock conceived the ideas. Charlie J. Gardner led the writing of the manuscript. James M. Bullock helped to refine the manuscript. Both authors gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The study did not use any data.

ORCID

James M. Bullock https://orcid.org/0000-0003-0529-4020

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