Global Change Biology

WILEY

Global Change Biology

OPINION OPEN ACCESS

Whole-Earth: A Conservation-Planning Paradigm for a Changing Climate

Joshua J. Lawler[1] | John E. Gross[2] | Wendy B. Foden[3] | Guy F. Midgley[4]

[1]School of Environmental and Forest Sciences, University of Washington, Seattle, Washington, USA | [2]Climate Change Response Program, United States National Park Service, Fort Collins, Colorado, USA | [3]South African National Parks, Tokai, Western Cape, South Africa | [4]School for Climate Studies, Stellenbosch University, Stellenbosch, Western Cape, South Africa

Correspondence: Joshua J. Lawler (jlawler@uw.edu)

Received: 27 September 2024 | **Revised:** 18 April 2025 | **Accepted:** 28 April 2025

Keywords: biodiversity | climate change adaptation | connectivity | conservation areas | conservation mosaics | conservation planning | ecosystem services | OECMs | protected areas

ABSTRACT

Conservationists have called for conserving 30%–50% of the earth's surface to address the ongoing biodiversity and climate crises. To be successful, such an expansion of the global reserve network must meet climate-intensified challenges of species movements, ecological transformations, increasing human needs, and environmental injustices. These challenges will not be overcome by simply doubling or tripling the footprint of protected areas. Instead, successful biodiversity conservation will require planning for conservation mosaics—large, integrated landscapes, and seascapes composed of areas with different levels of protection and types of management—that cover the entire earth. Such mosaics can (1) increase landscape-scale coordination of conservation efforts, (2) increase landscape permeability, (3) sustain healthy human populations, and (4) reduce environmental injustices. We describe this more holistic spatial conservation paradigm and provide a framework for planning for conservation mosaics that addresses growing biodiversity conservation and human needs.

1 | Introduction

Species extinction rates currently exceed background levels by 1000 times, fueled in part by rapid land-use and marine resource-use intensification and exacerbated by climate change (Barnosky et al. 2011; Wiens 2016). These trends have inspired calls to safeguard biodiversity by expanding the global conservation estate to 30%–50% of the planet (Allan et al. 2022; CBD 2022; Wilson 2016). However, simply expanding traditional area-based conservation will create new challenges and likely fail to address the challenges that climate change poses both to biodiversity and to humans (Sengupta et al. 2024; Zabala et al. 2024).

Much area-based conservation planning to date has followed a western-centric protected area and unprotected matrix (the areas outside of protected areas) paradigm, often referred to as "fortress conservation" (Brockington 2002; Mahalwal and Kabra 2023). Fortress conservation assumes that to protect biodiversity, human disturbances need to be minimized and therefore, protected areas generally need to exclude human inhabitants and most human activities. Although there is increased focus on including humans in protected areas, much of the conservation-planning literature has operated within this paradigm, focusing exclusively on biodiversity targets or a combination of biodiversity targets and ecosystem services that are more compatible with biodiversity protection (e.g., carbon storage, water quality; Eken et al. 2004; Margules and Pressey 2000; Naidoo et al. 2008; Schuster et al. 2023; Zeng et al. 2022). Much of the protected area estate on the ground, particularly in the United States and parts of Europe and India, takes this approach. Although other parts of the world have developed more inclusive approaches to spatial conservation (Fa et al. 2020; Tran et al. 2020), such a dichotomy is still reflected in practice in some places (Domínguez and Luoma 2020).

Climate change challenges this protected-area paradigm in traditional and new ways. Many of these challenges arise from the fact that climate change is converting what were assumed to be relatively stationary ecosystems into highly dynamic systems undergoing sustained, directional change (Harris et al. 2018). Moving forward, protected-area planning will need to facilitate climate-driven species movements for thousands of species and ecological transitions for many of the earth's ecosystems. Climate change is also affecting people—increasing food and water insecurity, driving migrations, and exacerbating environmental injustices (IPCC 2023). It is now well recognized that planning for protected areas in the future will need to be just and fair and address societal needs. The Convention on Biological Diversity (CBD) explicitly recognizes the need to address both biodiversity and people in equitable ways in its twenty-three 2030 targets (CBD 2022). However, the dominant protected-area paradigm, and most of the recent conservation-planning literature, have focused almost exclusively on target three (conserving 30% of lands, waters, and seas—or 30×30 as this target has come to be called).

Here, we describe and advocate for a more comprehensive spatial conservation paradigm that involves planning for and coordinating conservation efforts across entire landscapes and seascapes that together cover most, if not all, of the earth's surface. Although our focus is on both lands and seas, for brevity, hereafter, we often use the term landscape. These landscapes, or what we refer to here as "conservation mosaics," are coherently managed areas consisting of zones with different levels of protection. This paradigm draws on the concepts of conservation areas (CBD 2018), other effective area-based conservation measures (OECMs) (Jonas et al. 2021), biosphere reserves (Batisse 1982; Purwanto et al. 2020), and other established alternatives to strictly protected areas (Zabala et al. 2024) to increase biodiversity protection across much of the planet in a way that facilitates climate adaptation for people and biodiversity. Such an approach has the potential to address not only CBD 2030 target three but most of targets one through fourteen.

We begin by clarifying the challenges to expanding the protected-area network using the traditional protected-area paradigm. We then articulate the conservation-mosaic paradigm, provide some examples, and introduce a framework for planning for mosaics that incorporates a range of climate-focused conservation actions and produces multifunctional landscapes and seascapes with variable levels of protection. These mosaics could increase connectivity by creating more permeable landscapes, provide for both people and biodiversity in a changing climate, and potentially reduce environmental injustices. Our framework incorporates key climate-adaptation strategies that conserve biodiversity within the context of a complex social-ecological system, rather than assuming we can simply protect nature. We conclude with a discussion of several of the elements that are important for the implementation of a conservation mosaic paradigm.

2 | Challenges to the Current Protected-Area Paradigm

Expanding the protected area network will face the increasing challenges of (1) climate-driven species movements, (2) growing human needs, and (3) environmental injustices.

2.1 | Climate-Driven Species Movements

Animals and plants with the capacity to disperse are shifting their ranges in ways that correspond with climate change (Hickling et al. 2006; Moreno-Rueda et al. 2012; Pinsky et al. 2013; Tingley et al. 2012). Species range shifts, in turn, entrain larger changes in ecosystems, including changes in ecosystem composition, structure, and function and, in some cases, ecological transformations (Crausbay et al. 2022; Pecl et al. 2017; Wallingford et al. 2020). More species movements and ecological transformations are certain, given rapid climate trends toward conditions not seen for millions of years (Blowes et al. 2019; Burke et al. 2018).

Despite the need to facilitate climate-driven species movements, today's protected-area network remains largely disconnected. Only about 10% of the world's protected areas are structurally connected (Ward et al. 2020). Far fewer are functionally connected—that is to say, connected by a corridor of more ecologically intact land that facilitates movement. Increasing functional connectivity would potentially allow species to move from site to site, tracking their climatic niches. Thus, protecting connectivity would not only facilitate individual species' adaptation to, and persistence under, climate change, but it could also facilitate ecological transformations and the development of novel ecosystems based on new combinations of regionally native biota.

In recent years, several approaches have been developed for specifically targeting areas to facilitate climate-driven movements (Littlefield et al. 2019). However, much like the dominant protected-area paradigm, many of these and other connectivity efforts focus on protecting corridors of intact land amidst a matrix of human-dominated lands (Beier 2012; Krosby et al. 2018; Nuñez et al. 2013). Although such corridors can be effective, the amount of movement that climate change requires of species likely necessitates more connectivity than a network of relatively narrow protected corridors can provide. Furthermore, the amount of land needed to connect the existing network of strictly protected areas in this way, not to mention an expanded network, is substantial.

The scale of effort needed to facilitate movement and persistence of species and habitats will require many conservation actions that take place outside of strictly protected areas. Relatively few recommended climate-adaptation strategies for biodiversity focus only on protected areas (e.g., protecting key biological features). Most of the twenty-four most frequently mentioned recommendations in the scientific literature from 2007 to 2017 (McLaughlin et al. 2022) are applicable to both protected areas and the matrix surrounding them (e.g., increasing connectivity, managing the matrix; Table 1). To date, however, spatial conservation planning efforts have rarely incorporated the vast

TABLE 1 | The 24 most cited recommended actions to conserve biodiversity in the face of climate change from 2007 to 2019 (McLaughlin et al. 2022).

Recommended conservation actions for conserving biodiversity in the face of climate change	
• Protect or restore ecosystem function	• Manage for community/ecosystem diversity
• Increase connectivity	• Manage for future adapted species
• Manage for climate change refugia	• Manage fire
• Mitigate non-climate threats	• Protect key biotic features
• Conduct monitoring	• Manage for species diversity
• Climate adaptive assisted migration	• Manage the matrix
• Manage at larger scales/across scales	• Manage surface hydrology
• Manage for genetic/phenotypic diversity	• Manage climate change threats in combination with other threats
• Forest management	• Plant vegetation
• Manage for climate adapted genetics	• Reduce pollution
• Adaptive management	• Captive breeding at botanic gardens/zoos
• Target future conditions through habitat protection and restoration	• Riparian management

Note: Each action was cited at least five times. Actions appear in declining order (proceeding through left column then right) based on the number of papers in which they were cited, although multiple actions were cited at the same rate.

majority of these actions (Reside et al. 2018). Actions such as managing forests, restoring ecosystem functions, managing the matrix, and managing at larger scales have generally been seen as outside the purview of spatial conservation planning for climate change.

2.2 | Growing Human Needs

Climate change and its effects on species and ecosystems are having increasing impacts on human communities—impacts that are projected to become more severe and extensive (IPCC 2022). Crop yields are projected to decrease, with the production of soy, wheat, rice, and maize estimated to decrease between 3% (soy) and 7% (±4.5%, maize) per degree C of warming (Asseng et al. 2015; Zhao et al. 2017). Fisheries productivity may drop by 3M metric tons per degree C (Cheung et al. 2016). By 2050, nutrition security may be a greater challenge than food security in general (Nelson et al. 2018). In addition, climate change may result in a shift and/or increase in the global footprint of agriculture (Bayer et al. 2023; Ramankutty et al. 2002; Zabel et al. 2014). For example, as much as three quarters of the boreal forest is projected to become climatically suitable for agriculture by 2099 (King et al. 2018), potentially leading to a northward expansion of wheat production (Kettlewell et al. 2023). Although such an expansion may increase or offset losses in food production, it would likely stimulate the conversion of forest ecosystems to intensive agriculture.

Increasing temperatures are also likely to drive human migration and displacement. Much of the human population lives in areas where projected warming is above average, making effective exposure, on average, 2.3 times the mean global warming (Xu et al. 2020). By 2070, one-third of the human population will, on average, experience mean annual temperatures greater than or equal to 29°C—temperatures found today only on the hottest 0.8% of the planet (Xu et al. 2020). Thus, in addition to the actions taken to address food and water scarcities, human adaptation efforts will likely include rapidly increasing migration and associated expansion or shift of urban areas.

2.3 | Environmental Injustices

Allan et al. (2022) calculated that 44% of the planet is needed for protecting biodiversity and that 44% is currently home to 1.87 billion people. In many historical cases, the establishment of protected areas has involved the forced removal of people. Although the published record of evictions is almost certainly incomplete, it indicates that, by area, the establishment of a significant portion of the conservation estate has resulted in evictions of residents—the majority of those recorded have occurred in Africa, South and Southeast Asia, and North America (Brockington and Igoe 2006). An estimated 900,000 to 14.4M people have been evicted from protected areas in Africa alone (Geisler 2003; Geisler and De Sousa 2001). Indigenous people are currently threatened with removal from lands in India, the Democratic Republic of Congo, and Kenya (Domínguez and Luoma 2020). It is important to note that displacement from the land takes more forms than eviction and can include displacement from resources (Coad et al. 2008). Displacements often impact Indigenous populations, and although there has been a call and arguments for a new conservation paradigm, the practice of removal prevails in many places (Domínguez and Luoma 2020).

3 | Conservation Mosaics

As an alternative to planning for the expansion of a protected area network to cover 30%–50% of the planet, we advocate for planning for conservation mosaics that cover most of the earth's surface. These mosaics would have the objectives of increasing landscape-scale coordination of adaptation efforts, increasing landscape permeability (the degree to which an area facilitates the movement of organisms), sustaining healthy human populations, and reducing environmental injustices (Figure 1). Such mosaics would include a spectrum of different levels of protection, human activity, and management and regulation, all coordinated at the landscape level to foster high returns on conservation investments that increase both the overall proportion of the landscape that supports biodiversity conservation and humanity's connection with and benefit from natural systems.

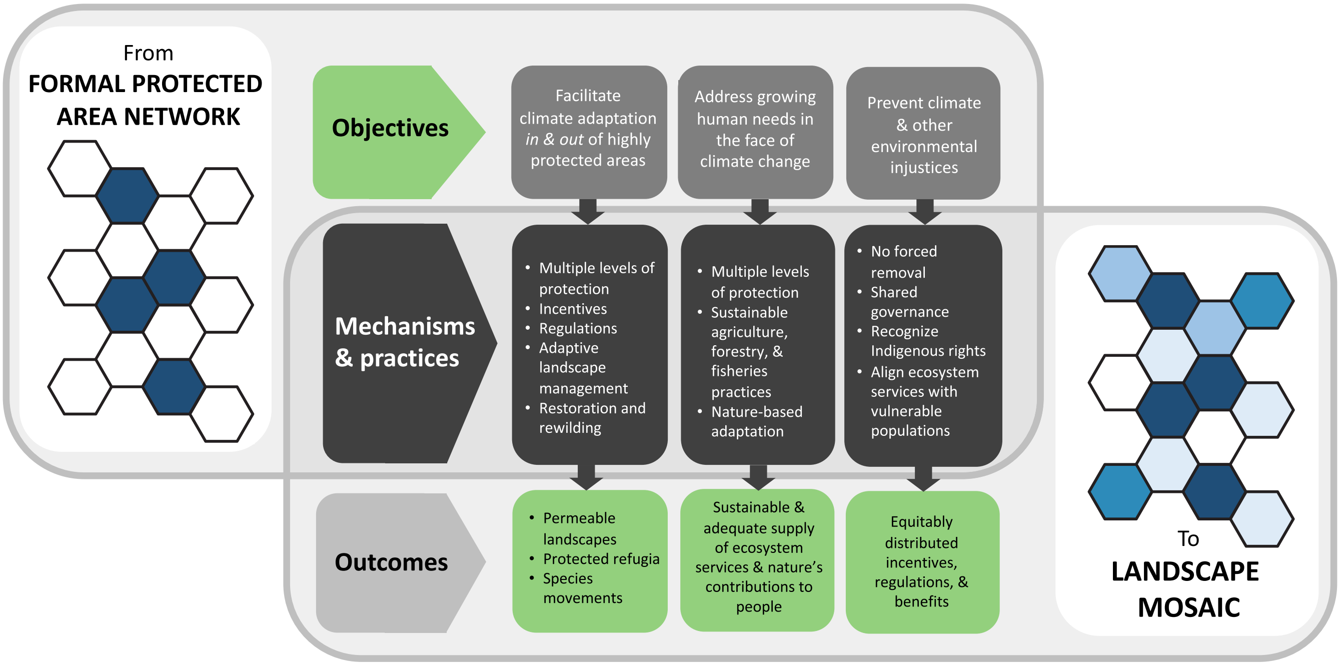


FIGURE 1 | Framework for successful biodiversity conservation in the face of climate change. The framework includes three key objectives that an expanded network of protected areas will need to meet, in addition to providing adequate protection for biodiversity. It also includes lists of example mechanisms and practices for meeting those objectives as well as expected outcomes. The schematics on either side of the framework provide conceptual depictions of the protected area paradigm (left) and conservation landscape mosaic approach (right) to spatial conservation. Many management units, particularly large ones, would apply different levels of protection in different places, in the same way that, for example, the U.S. National Park System applies stringent wilderness protections in high-value areas of some parks.

Areas within the mosaic would range from more strictly protected ones with little detrimental human activity to areas with relatively little protection that allow many more human activities (Figure 2). This model aligns with a 2018 decision by the Parties to the Convention on Biological Diversity that recognized the need for expansion beyond a strictly protected-areas focus to a broader "conserved-area paradigm" (CBD 2018).

Conservation mosaics have the potential to address the three challenges laid out earlier: climate-driven species movements, growing human needs, and environmental injustices. They also have the potential to address many of the CBD 2030 targets one through fourteen. Accomplishing any of these goals, however, will depend on how the concept is implemented.

3.1 | Creating Permeable Landscapes

Coordinating conservation actions across lands with different levels of protection could greatly increase our ability to create permeable landscapes that facilitate species movements. For example, portions of the landscape receiving lower levels of protection could be targeted for restoration or management actions that allow for movement between more protected areas of species that are less tolerant of humans even if those parts of the landscape do not necessarily support viable populations themselves. Most animals clearly prefer and more rapidly transit unmodified habitats, but many terrestrial species will move and disperse in human-occupied—and sometimes very strongly human-dominated—landscapes (Kauffman et al. 2021; Tucker et al. 2018).

A conservation-mosaic paradigm facilitates a shift from connective corridor planning focused on narrow, highly protected strips of land to managing the landscape for permeability. Enhancing permeability could include altering land-use practices, restoring key pinch points—where human land use is disproportionately preventing species movements—and helping species cross roads, fence lines, and other barriers to movement. Landowner incentives, land-use regulations, zoning, and density regulations associated with large portions of the landscape could be designed to increase landscape permeability for species that are less tolerant of humans (Jayadevan et al. 2020). Approaches have been suggested for doing so in managed forests by, for example, retention harvests, riparian protection, longer rotations, mimicking natural disturbance regimes, and understory management (Lindenmayer and Franklin 2002) and in agricultural landscapes by creating uncropped margins, hedgerow planting and restoration, reduced pesticide and fertilizer use, and summer fallows (Donald and Evans 2006; Vickery et al. 2004). Enhancing permeability in more residential areas might involve planning for growth that better retains green spaces with native vegetation, promoting landscaping with native vegetation that provides for pollinators and birds, promoting park lands, creating more natural paths through developed areas, and concentrating growth in core urban areas (Smith et al. 2019). Overcoming barriers such as roads and fences will require multiple targeted efforts (e.g., of underpasses and overpasses), perforating these structures to improve permeability.

Shifting from a focus on corridors to landscape permeability comes with additional benefits and challenges. For example, focusing on permeability has the potential to include a broader

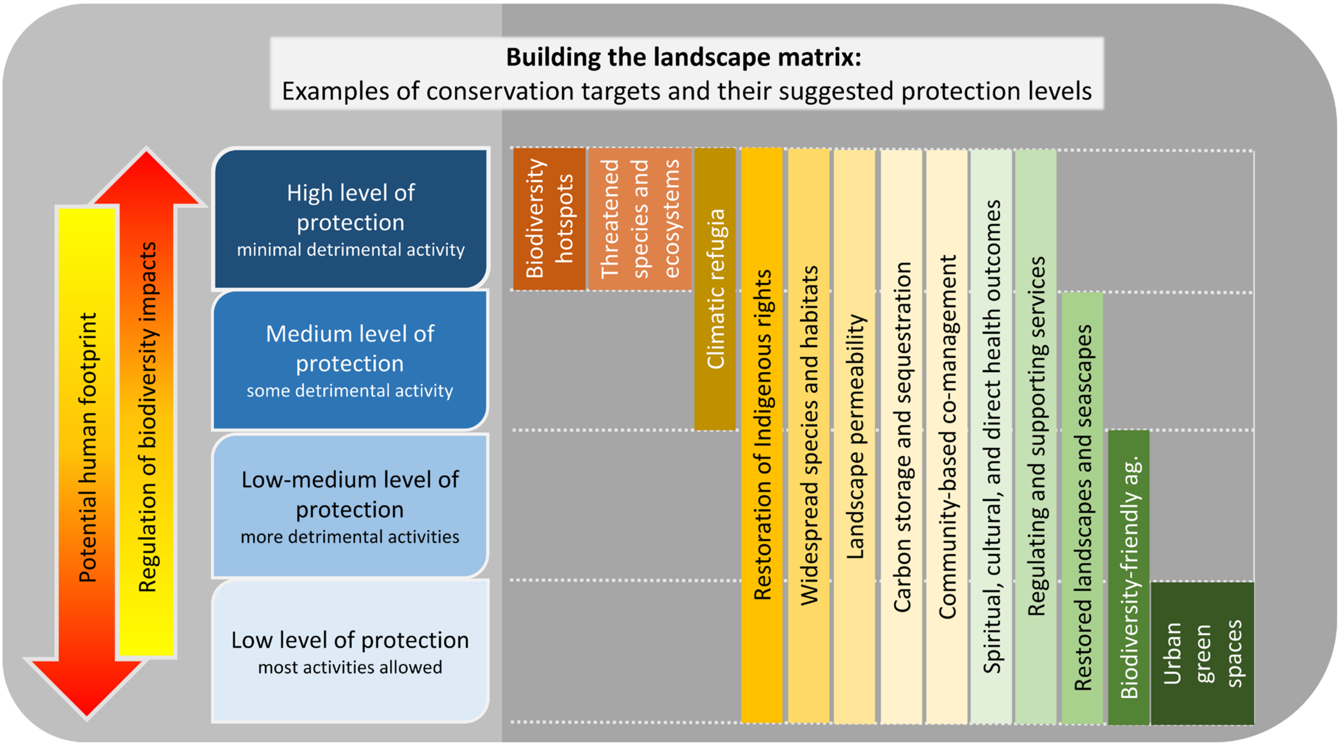


FIGURE 2 | Conservation actions and how they could be served by different levels of protection. The stack of blue boxes depict four different levels of biodiversity protection. The highest levels of protection (darker blue boxes) are associated with the least human impact and the most stringent regulations (yellow-red arrows to the left). The vertically oriented boxes to the right represent conservation actions that could be taken in lands with different degrees of protection. The extent and position of the vertical boxes represent what are likely to be common scenarios. However, the figure is not meant to imply that the conservation of some targets or that some actions could not occur on lands with other levels of protection than those overlapped by the vertically aligned boxes (e.g., some types of restoration can and do occur in highly protected areas and some threatened biodiversity elements occur in developed landscapes).

array of taxa. Much connectivity modeling to date has focused on vertebrates. Although corridors could easily be designed for multiple species, the concept of a permeable landscape in which much more of the land surface of the earth is in a semi-natural state could facilitate the movement of many more species—including plants, fungi, and invertebrates. More permeable landscapes will likely also lead to more interactions between humans and the natural world. This could have beneficial outcomes for mental and physical health (Frumkin et al. 2017) but could also lead to more human-wildlife conflict (Abrahms et al. 2023). Although enhancing permeability will likely serve many species well, some species show high site fidelity (e.g., to breeding colony locations), preventing range shifts, or cannot move fast or far enough to track their shifting climate niches without human assistance (i.e., translocation; Corlett and Westcott 2013; Pecl et al. 2017; Schloss et al. 2012). Enhancing landscape permeability helps achieve CBD 2030 targets one, eight, twelve, and fourteen.

3.2 | Supporting Healthy Human Communities

For conservation landscapes and seascapes to succeed, people's basic needs must be met (Zhang et al. 2020). Planning for whole landscapes and seascapes as conservation mosaics has the potential to more effectively incorporate the multiple competing needs of human and non-human species and in so doing provide more optimal solutions for biodiversity (addressing CBD 2023 targets five, nine, and eleven). Conservation mosaics will still need to facilitate the production of food and fiber, the creation of shelter, the generation of electricity, and extraction of minerals and other materials. Each of these activities, to different degrees, conflicts with the protection of biodiversity, and each can be undertaken in ways that have a range of impacts on biodiversity. The types of regulations and constraints on (as well as incentives for) different approaches to each of these activities could be determined in a coordinated conservation-planning effort for the whole landscape. Areas with the potential to provide for more biodiversity could have more constraints and incentives than areas with less potential.

Urban areas, intensely farmed areas, mines, timberlands, and the oceans can all be managed in ways that both improve human health, favor biodiversity, and increase permeability (addressing CBD 2023 targets seven, ten, and twelve). Reducing pesticide and fertilizer use can both benefit human health and biodiversity. Diversifying croplands, reducing field sizes, and allowing at least 20% of the landscape to be in a semi-natural state can significantly increase biodiversity (Tscharntke et al. 2021). Similarly, in areas focused on timber production, forestry practices can be modified to provide more habitat with mixed, multi-aged forest stands, gap creation, and retention harvests (Lafond et al. 2015). Although mines create impacts that are hard to avoid, management of the areas around mines and post-mining remediation can reduce impacts. In cities, increasing green space, including parks, community gardens, green rooftops, bioswales, and street trees all have the potential to increase human health and positively affect biodiversity. Addressing fishing impacts involves a suite of management tools such as total allowable catches, gear restrictions, size restrictions, access rights, habitat restoration, non-native species removal, and quotas, which can all be applied spatially (Lapointe et al. 2014; Sumaila et al. 2016). Applying such sustainable approaches will require incentivizing farmers, foresters, fishers, and land- and property-owners to be stewards through a combination of sustainable management practices, conservation, and restoration (Dudley and Alexander 2017). To increase biodiversity and permeability while safeguarding livelihoods, locating incentives and regulations, as well as more intensive agriculture, development, fishing, and forestry will need to be part of the conservation-planning process.

3.3 | Addressing Environmental Injustices

To date, the benefits from, and costs of, protected areas have been inequitably distributed (Bennett 2018; Zafra-Calvo et al. 2019). However, conservation mosaics themselves will not necessarily address environmental injustices. It would be entirely possible to design such landscapes in ways that perpetuate or even exacerbate current environmental injustices. CBD 2030 targets three and nine through eleven all call for providing for both people and nature and targets three, nine, eleven, and twelve specifically mention "recognizing indigenous and traditional territories, where applicable," "protecting and encouraging customary sustainable use by indigenous peoples and local communities," restoring, maintaining and enhancing "nature's contributions to people, including ecosystem functions and services…through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature," and "contributing to inclusive and sustainable urbanization." Adhering to these goals would provide a decent foundation for an inclusive and equitable approach to designing conservation mosaics that prevent future injustices.

Others have noted that a conservation mosaic-like approach that treats entire landscapes as socio-ecological systems provides an opportunity to reduce existing environmental injustices and prevent future ones (Loos 2021) while addressing biodiversity conservation needs (Büscher and Fletcher 2019; Massarella et al. 2022). Conservation mosaics can be designed to support people's continued occupation of and connection with the land and sea and supply food, fiber, and shelter—providing an alternative to the historical pattern of exclusion and forced removal that has typified much of historical protected-area establishment. Although there are plenty of protected areas that include human occupancy, conservation mosaics would allow for an even greater range of human activity. The coordination of activities across large landscapes would allow for the targeting of policies and restoration efforts specifically aimed to protect the most vulnerable human populations—either by improving ecosystem services and natural climate solutions or, alternatively, by minimizing constraints on human activity. Planning for such efforts could involve identifying sites using multi-objective optimization and multi-zonal conservation planning—both well-established tools in the conservation planning toolkit (Deléglise et al. 2024; Magris et al. 2017; Reyers et al. 2012).

As noted earlier, the establishment of protected areas has often impacted Indigenous populations. To address these inequities and injustices, expansion of the conservation area network into human-occupied areas requires, at the very least, recognition of Indigenous peoples' rights, as well as inclusive planning, management, and governance (Jacobs et al. 2022; Kiwango and Mabele 2022). Some protected area management agencies have explicitly recognized these needs in policy and program design (USDOI 2021; Van Cuong et al. 2017). Other partnerships have done more. In the northwestern United States, for example, a collaboration between the Colville Tribes, Conservation Northwest, and The Nature Conservancy resulted in the purchase and return of 3700 ha of land to the Okanogan people. The site was targeted based on the increased connectivity it would provide, particularly for carnivores like lynx and wolverine.

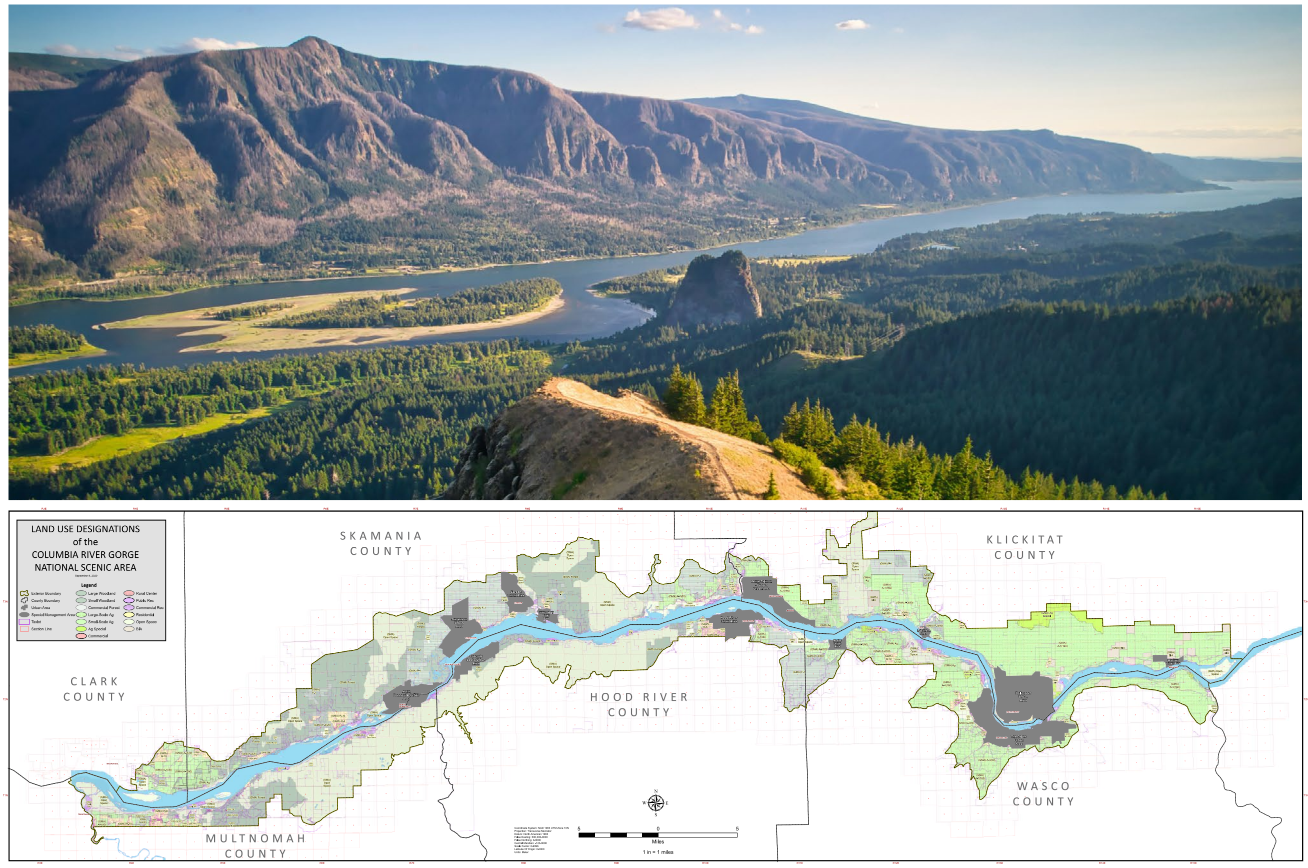
To help prevent future injustices, Indigenous local community leadership will need to play a key role in promoting just and effective governance for both social and ecological outcomes (Artelle et al. 2019; Dawson et al. 2021). There have been numerous calls for shared and inclusive decision making in the establishment and management of marine, terrestrial, and freshwater conservation areas (Bennett 2018; Kiwango and Mabele 2022; Shah and Rodina 2018), as well as guidance for doing so more effectively (Kiwango and Mabele 2022). There are good examples of Indigenous-led and co-managed conservation areas around the world, including the well-established Indigenous Protected Areas in Australia (Muller 2003; Ross et al. 2009), co-managed marine protected areas (Masud et al. 2022), and co-managed extractive forestry reserves in Brazil (Prado et al. 2022). Community conservation areas cover more land than national parks in Namibia and Kenya (Nelson et al. 2021). Good examples of successful conservation also come from Indigenous territories (Baragwanath and Bayi 2020; Fa et al. 2020; Schleicher et al. 2017). Nonetheless, it is important to note that community conservation efforts often face many challenges, such as being appropriated by the state. In addition, not all such approaches have been successful from a biodiversity conservation perspective; however, and therefore—as with all environmental stewardship—careful consideration of context and a learning-based approach are important.

4 | Existing Landscape Mosaics

Good examples of conservation mosaics exist on the landscape today. These include UNESCO Biosphere Reserves (UNESCO 2021) such as Guadalupe Island or the Orinoco Delta reserves in Mexico and Venezuela. These reserves have areas zoned for different levels of conservation and different human activities. In the United States (U.S.), the Columbia Gorge National Scenic Area is a collaboratively governed landscape with zoning that ranges from strictly protected areas to urban areas with few regulations (Box 1). In South Africa, South African National Parks is working with partners to design landscapes with multiple land ownerships and different levels of protection (Box 2).

BOX 1 | Columbia Gorge National Scenic Area: A conservation landscape mosaic.

The Columbia Gorge National Scenic Area in the northwestern U.S. was established in 1986 to protect the scenic beauty of the Columbia Gorge, a canyon on the Columbia River. Despite being designated to protect scenic beauty, not biodiversity, it provides a good example of a mosaic of lands with multiple levels of protection and different regulations, and is co-managed by Tribes, States, and the Federal government. All lands of the scenic area fall into three categories: Special Management Areas, General Management Areas, and Urban Areas. The Special Management Areas have the highest level of protection and are managed by the U.S. Forest Service. The General Management Areas have the next highest level of protection and include multiple uses, including logging, farming, public recreation, rural residential areas, and grazing. Development is subject to multiple regulations and any proposed development on private land is managed by the Gorge Commission and six counties. Development on public land is managed by the U.S. Forest Service. The Gorge Commission is composed of members from two states and six counties as well as a non-voting representative from the U.S. Forest Service. As of summer 2024, the chair and at least one of the other commission positions were held by Tribal members. The Commission works with the following four Tribal nations with treaty rights on the Columbia River: the Confederated Tribes of the Warm Springs, Yakama Nation, Nez Perce Tribe, and the Confederated Tribes of Umatilla Indian Reservation. The Forest Service also consults with the Confederated Tribes of the Grand Ronde, the Cowlitz Tribe, and the Siletz Tribe. The Scenic Area also includes 13 urban areas that are exempt from the Scenic Area regulations.



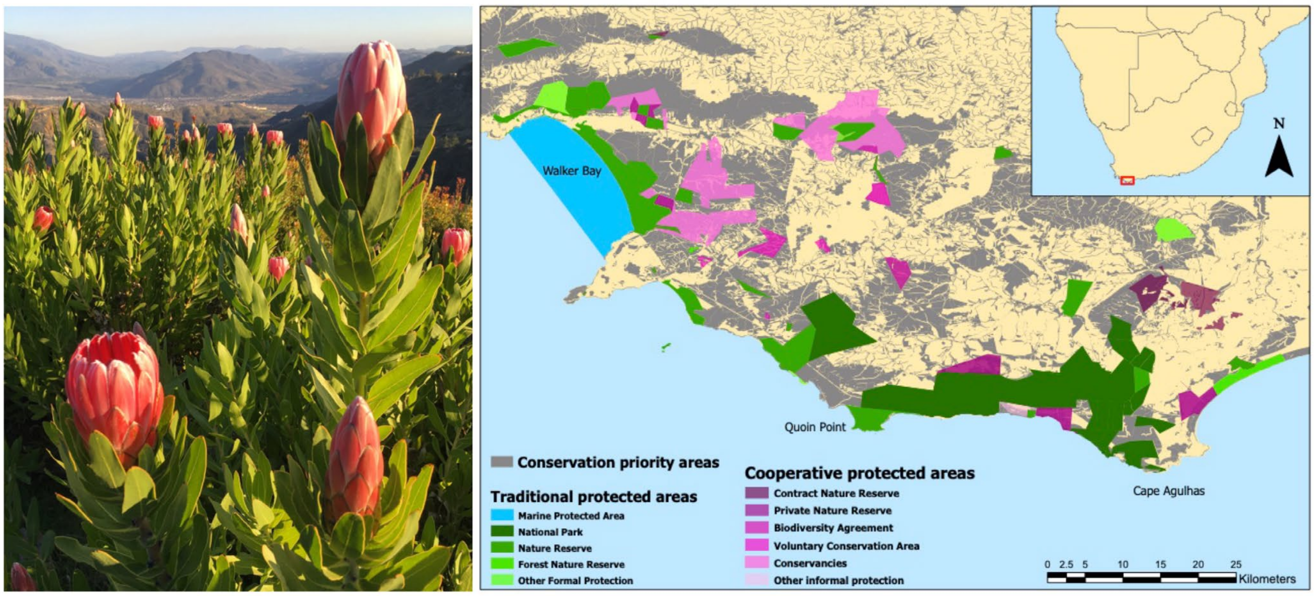
The Columbia River Gorge and map of the Columbia Gorge National Scenic Area. Photo credit: Ruvim Miksanskiy. Map credit: Columbia River Gorge Commission.

5 | A Spatial Planning Framework for Creating Conservation Mosaics That Address Climate Change

Designing conservation mosaics that address climate change requires not only identifying areas to receive high levels of protection, but also identifying areas in which management, restoration, and lower levels of protection can facilitate species movements and other adaptive responses while still providing for growing human needs. Here, we suggest a decision-making framework for designing conservation mosaics with different levels of protection and management that incorporates multiple climate change-focused conservation strategies and the provision of ecosystem services (such as agricultural production and housing) that are generally less compatible with biodiversity conservation (Figure 3). The framework informs decisions on the level of protection an area might have and management approaches, regulations, and incentives that may be needed. Although other conservation planning efforts have

BOX 2 | South Africa: Creating a conservation landscape mosaic.

South Africa's area-based conservation framework outlines a hierarchy of possible voluntary biodiversity stewardship agreements in three categories (SANBI 2018). Category 1 (Protected Areas) includes national parks, nature reserves, and protected environments, which have been declared under the country's National Environmental Management Protected Areas Act (Act 57 of 2003). They have the highest protection status, biodiversity importance, and conservation support, and most restrictive land-use conditions. Those managed as Category 2 (Conservation Areas) have less restrictive land-use conditions but are considered contributors to the broader conservation estate. Under Category 1, nature reserve and contract national park biodiversity stewardship agreements provide eligibility for income tax deductions under the South African Income Tax Act (Act 58 of 1962). Selective stewardship agreements under Categories 1 and 2 allow for municipal property rates exclusion, rebate, or reduction in terms of the Municipal Property Rates Act where the local authority makes provision for this in their respective property rates policies. Category 3 (Partnership Areas) is an informal biodiversity stewardship category involving registration of a site within this category by the provincial conservation authority or conservation non-governmental organization. Together, categories 2 and 3 are regarded as OECMs. Each of the three categories has multiple designations under it, each with different regulations and use allowances. For example, Category 2 Business, Industry, and Biodiversity Initiatives can involve sustainable farming and watershed stewardship activities. Category 3 designations include biosphere transition zones, which can allow some timber harvest and cattle grazing. The map shows area-based protection of the Cape Agulhas region of South Africa with potential for expansion to create a conservation mosaic. Traditional protection mechanisms (blue and green areas) are supplemented by stewardship and co-management protection (pink and purple areas). The grey areas have been identified as important for biodiversity and could be added to the network with different levels of protection and management to create a conservation landscape mosaic.



Fynbos and map of area-based protection in the Cape Agulhas region of South Africa. Map lines delineate study areas and do not necessarily depict accepted national boundaries. Map credit: South African National Parks.

demonstrated zonal planning for multifunctional landscapes (e.g., Reyers et al. 2012) or have integrated climate adaptation strategies into conservation planning (e.g., Game et al. 2011), we are unaware of a framework that provides guidance on planning for multiple levels of protection to plan for whole landscapes that address climate impacts for nature and people.

Our description of the framework (Figure 3) identifies a limited set of conservation actions that have been suggested for addressing climate change. These include protecting climatic refugia, increasing permeability, protecting rare geophysical settings, managing for ecological transitions, and restoring degraded systems. Climatic refugia (hereafter "refugia") are areas in which climatic conditions are likely to remain, at least for a period of time, more suitable for the local flora and fauna than the surrounding landscape (Ashcroft 2010; Keppel et al. 2012; Morelli et al. 2016). Such areas have been important for biodiversity in the past and are likely to play an important role in conservation today. Protecting a diversity of geophysical settings has also been suggested as a planning tool to address climate change (Lawler et al. 2015). As species move and reorganize into new communities, protecting a diversity of geophysical settings could provide a diversity of conditions for these new communities. There are, as noted in Table 1, many more management and planning actions that could be incorporated into a framework like the one we present. Those we have included are meant to provide an example that could be expanded upon.

The first steps in the decision-making framework involve determining the degree to which an area supports one or more

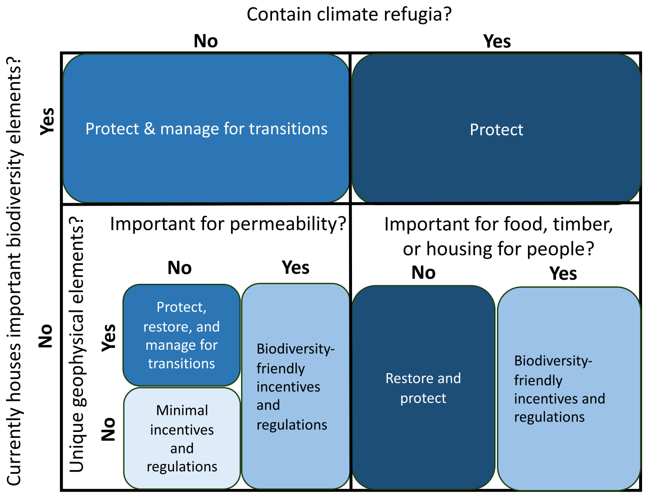


FIGURE 3 | A framework for creating conservation mosaics that conserve biodiversity and climate refugia and provide for human needs and landscape permeability. Answers to questions at the top and left-hand sides of the figure categorize a given area into one of four quadrants, with the top quadrants indicating appropriate approaches and the bottom quadrants each presenting another pair of questions to determine the appropriate approach. Note that, as in Figure 2, darker blue tones indicate higher levels of protection. Note that areas that currently house important biodiversity elements (i.e., upper two quadrants) may in some cases require restoration to address historical impacts (e.g., wildland fire suppression).

elements of biodiversity (Watson et al. 2023) and whether or not the area is likely to contain one or more climatic refugia. To date, selecting areas that play an important role in supporting biodiversity has been at the heart of systematic conservation planning (Margules and Pressey 2000) and a number of approaches and tools could be used to assess the value of specific areas for biodiversity (Ball et al. 2009; Moilanen 2007). Such approaches would take into account long-standing spatial conservation principles such as redundancy (e.g., protecting multiple populations of species) and positive net conservation outcomes (Bottrill and Pressey 2012; Bull et al. 2020; Groves and Game 2016; Pressey et al. 2021). Current patterns of biodiversity are used in these prioritizations, but planners are increasingly also using projections of potential future biodiversity patterns (e.g., Wu et al. 2018).

Areas that are important for protecting significant elements of biodiversity and are identified as refugia are likely to be among the most critical parts of the landscape for protecting biodiversity—especially low-motility species—in a changing climate, particularly in the near term. Correspondingly, these areas are generally a high priority, deserving the highest level of protection and the strictest restrictions on detrimental human activities. They will likely need to be lands that are already in the public domain or are purchased for the express purpose of conservation. As such, these areas can provide new opportunities for developing co-management strategies and otherwise recognizing Indigenous peoples' rights. Areas that are important for protecting biodiversity today, but are not likely to serve as refugia, might receive a medium level of protection and be the focus of management actions to facilitate ecological transitions along preferred trajectories.

Areas that do not support important elements of biodiversity but do serve as climatic refugia could receive varying levels of protection depending on the degree to which there are other competing demands on the land uses that are in conflict with biodiversity conservation. For example, areas important for food production, timber, or fish harvest, or housing might receive lower levels of protection and allow for more human activity. These areas could also have substantial incentives for practices that minimize impacts on species and ecosystems (Lentz and Christenson 2011). For example, areas that are in high demand for exurban development could receive protections that constrain the type and pattern of development, including requiring larger natural and more protected spaces among the developments. Areas that are likely to contain refugia and are not critical for human activities that conflict with biodiversity conservation could be restored and protected at a relatively high level. These areas could also serve as areas into which rarer species might move as the climate changes.

For areas that are not likely to support important biodiversity elements nor serve as refugia in the future, one could determine the degree to which, if protected or restored, they would increase landscape permeability. Areas that have the potential to play a significant role in ensuring landscape permeability could receive low to medium levels of protection but be the focus of substantial incentives and regulations for restoration and protection. For areas that are not likely to play a role in increasing permeability for climate-driven movements, one could ask whether or not they harbor unique geophysical settings. Those that do could be the target of protection, restoration, and management for transitions to provide areas where unique combinations of species could establish in the future. Those that do not harbor such unique geophysical settings could receive the lowest levels of protection from human activities.

6 | Implementation

6.1 | Coordinating Conservation Efforts

Having multiple levels of protection in a landscape is an established concept and a reality in much of the world. Lands and waters with different ownerships and lands managed by different governmental agencies often have different levels of protection and allow different activities. However, these lands are rarely organized into larger landscapes with collaborative governance to facilitate conservation actions across all of the lands and waters therein. Collaborative governance for conservation can involve the coordination of planning and action across multiple landowners, regulatory and governing entities, and other actors such as conservation non-governmental organizations and other stakeholders. It can take the form of co-management regimes, collaborative public management, nested governance, community-centered governance, and multi-partner governance (Armitage et al. 2020; Armitage et al. 2009; Visseren-Hamakers et al. 2012; Wyborn and Bixler 2013). Effective collaborative governance is critical to implementing the conservation mosaic concept.

Collaborative governance can address the mismatch between the scales of functioning ecological systems and established social systems (Cumming et al. 2006; Wyborn and Bixler 2013). In the case of large-scale conservation mosaics, collaborative governance would foster the coordination of climate adaptation actions not generally considered in the spatial conservation planning process, thus allowing them to be strategically placed across the broader landscape. For example, coordinated conservation efforts can greatly increase the effectiveness of ecological restoration on connectivity across a large landscape (Neeson et al. 2015). Collaborative governance can also increase the pace and scale of restoration efforts (McIntyre and Schultz 2020). Although good examples of collaborative governance and conservation are growing (Box 1; McIntyre and Schultz 2020), there are still questions about exactly how and under what circumstances collaborative governance leads to positive ecological and social outcomes (Bodin 2017; Clement et al. 2020). Fortunately, the number of frameworks and tools for assessing the effectiveness of collaborative conservation and governance is also growing (Clement et al. 2020; Emerson and Nabatchi 2015).

Although collaborative governance could take many forms in a conservation mosaic, the governing body that oversees the Columbia Gorge National Scenic Area (Box 1) provides one example. This body is composed of appointees from multiple Tribal Nations and three levels of U.S. government (smaller counties, larger states, and one non-voting federal representative). Although the body governs the area and makes decisions on development proposals, management of the lands within the area is still overseen and carried out by the individual jurisdictions. Zabala et al. (2024) provide the additional example of EUROPARC-Spain, which serves as a transversal actor by facilitating cooperation across parties and protected areas.

6.2 | Flexible Land Protection Tools

Many tools for creating large-scale conservation mosaics already exist. For example, other effective area-based conservation measures (OECMs) (Gurney et al. 2021; Jonas et al. 2021) would play an important role in such landscapes and seascapes. OECMs are already expanding the scope of area coverage, governance authorities, role-players, rights-holders, land-use types, and sectors that may be engaged and recognized in conservation efforts (Dudley et al. 2018; Jonas et al. 2021; Marnewick et al. 2021). As countries incorporate OECMs into national conservation networks, evidence of successful application is accumulating. One such success is the governance of Ziro Valley agrosystems by India's Apatani tribe in Arunachal Pradesh, where traditional agricultural practices, which protect biodiversity, are maintained through combined traditional and statutory governance systems (Dollo et al. 2009).

6.3 | Regulations and Incentives

Conservation in areas with lower levels of protection can be achieved through land-use regulations, incentives, zoning, and density regulations. Multiple examples of such tools exist. In the U.S., programs like the Conservation Reserve Program, Agricultural Conservation Easement Program, and the Conservation Stewardship Program all offer incentives to farmers for enacting conservation measures on their lands. Land-use management laws that require setbacks from steep slopes or riparian buffers are another example of tools that can be used to increase the conservation value of lands with relatively little protection. These laws have primarily focused on human safety and water quality, but some, like the U.S. Endangered Species Act, focus explicitly on conserving biodiversity. Planning for entire landscape conservation mosaics would allow planners and managers to apply incentives and restrictions where they are most needed and to coordinate efforts across areas and jurisdictions.

6.4 | Small-Scale Land Management

In the conservation mosaic model, smaller and more developed areas can contribute to achieving biodiversity targets (Wintle et al. 2019). Even urban areas can harbor important elements for conserving biodiversity (Lepczyk et al. 2023). Active management for biodiversity in urban areas and agricultural landscapes has co-benefits for human inhabitants because more natural landscapes can improve human health in multiple ways (Frumkin et al. 2017; Kirk et al. 2021) and contribute to more permeable landscapes in the areas between larger and wilder protected areas (Ossola et al. 2019; Ribeiro et al. 2022). Conservation mosaics with coordinated, collaborative governance would allow planners to target specific areas for incentives and regulations that foster landscape permeability where it is most needed.

7 | Conclusions

Broad-scale conservation that truly addresses biodiversity protection, landscape permeability, growing human needs, and environmental justice will require managing whole landscapes as complex social-ecological systems. To be successful, implementing conservation mosaics will likely require a change in the way many cultures view the relationship between humans and nature, transitioning from a dualistic relationship in which humans are separate from nature to one in which humans are part of nature and a shift away from a protectionist and consumptive attitude towards a nurturing, collaborative, and sustainable one (Büscher and Fletcher 2019). Such shifts entail envisioning and managing conservation mosaics as human-social-ecological systems rather than largely focusing on the management of ecological systems in strictly protected areas. In turn, managing human social-ecological systems will necessitate a broader leadership and management team—one that includes natural resource specialists in collaboration with community leaders, Indigenous knowledge holders, economic experts, and others.

Such a shift in the protected area paradigm will be challenging. However, truly addressing the climate crisis requires a massive effort to change energy systems, food systems, transportation, housing, economies, and possibly systems of governance. Relative to these changes, a shift in perspective from one that sees humans and nature as separate to one that views people as integral parts of ecosystems—the functions of which we depend upon—may not be such a stretch. Such a shift in perspective could lead to a new ethic and a more sustainable, greener world in which conservation mosaics and the regulations, incentives, and management they require are accepted and embraced.

Author Contributions

Guy F. Midgley: conceptualization, writing – review and editing. **Joshua J. Lawler:** conceptualization, project administration, writing – original draft, writing – review and editing. **John E. Gross:** conceptualization, writing – original draft, writing – review and editing. **Wendy B. Foden:** conceptualization, writing – original draft, writing – review and editing.

Acknowledgments

Gregor Schuurman contributed to this paper as a co-author throughout its development, but his employer, the U.S. National Park Service, denied him permission to be listed as an author because of the paper's support for environmental justice; diversity, equity, and inclusion; and environmental regulation conflicts with Trump Administration executive orders. We thank Zishan Ebrahim for his help with the map of the Cape Agulhas region as well as Leticia Santillana Fernández, Sarah MacFarland, Fern Crossway, Leo Wahl, Aji John, Ben Sullender, Vivian Hawkinson, Danielle Horne, Timothy Chen, and James Strand for valuable discussions.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The submitted opinion piece does not include any original data.

References

Abrahms, B., N. H. Carter, T. J. Clark-Wolf, et al. 2023. "Climate Change as a Global Amplifier of Human–Wildlife Conflict." *Nature Climate Change* 13, no. 3: 224–234. https://doi.org/10.1038/s41558-023-01608-5.

Allan, J. R., H. P. Possingham, S. C. Atkinson, et al. 2022. "The Minimum Land Area Requiring Conservation Attention to Safeguard Biodiversity." *Science* 376, no. 6597: 1094–1101. https://doi.org/10.1126/science.abl9127.

Armitage, D., P. Mbatha, E.-K. Muhl, W. Rice, and M. Sowman. 2020. "Governance Principles for Community-Centered Conservation in the Post-2020 Global Biodiversity Framework." *Conservation Science and Practice* 2, no. 2: e160. https://doi.org/10.1111/csp2.160.

Armitage, D. R., R. Plummer, F. Berkes, et al. 2009. "Adaptive Co-Management for Social–Ecological Complexity." *Frontiers in Ecology and the Environment* 7, no. 2: 95–102. https://doi.org/10.1890/070089.

Artelle, K. A., M. Zurba, J. Bhattacharyya, et al. 2019. "Supporting Resurgent Indigenous-Led Governance: A Nascent Mechanism for Just and Effective Conservation." *Biological Conservation* 240: 108284. https://doi.org/10.1016/j.biocon.2019.108284.

Ashcroft, M. B. 2010. "Identifying Refugia From Climate Change." *Journal of Biogeography* 37, no. 8: 1407–1413. https://doi.org/10.1111/j.1365-2699.2010.02300.x.

Asseng, S., F. Ewert, P. Martre, et al. 2015. "Rising Temperatures Reduce Global Wheat Production." *Nature Climate Change* 5, no. 2: 143–147. https://doi.org/10.1038/nclimate2470.

Ball, I. R., H. P. Possingham, and M. Watts. 2009. "Marxan and Relatives: Software for Spatial Conservation Prioritisation." In *Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools*, 185–195. Oxford University Press.

Baragwanath, K., and E. Bayi. 2020. "Collective Property Rights Reduce Deforestation in the Brazilian Amazon." *Proceedings of the National Academy of Sciences of the United States of America* 117, no. 34: 20495–20502. https://doi.org/10.1073/pnas.1917874117.

Barnosky, A. D., N. Matzke, S. Tomiya, et al. 2011. "Has the Earth's Sixth Mass Extinction Already Arrived?" *Nature* 471, no. 7336: 51–57.

Batisse, M. 1982. "The Biosphere Reserve: A Tool for Environmental Conservation and Management." *Environmental Conservation* 9, no. 2: 101–111. https://doi.org/10.1017/S0376892900019937.

Bayer, A. D., S. Lautenbach, and A. Arneth. 2023. "Benefits and Trade-Offs of Optimizing Global Land Use for Food, Water, and Carbon." *Proceedings of the National Academy of Sciences of the United States of America* 120, no. 42: e2220371120. https://doi.org/10.1073/pnas.2220371120.

Beier, P. 2012. "Conceptualizing and Designing Corridors for Climate Change." *Ecological Restoration* 30, no. 4: 312–319. https://doi.org/10.3368/er.30.4.312.

Bennett, N. J. 2018. "Navigating a Just and Inclusive Path Towards Sustainable Oceans." *Marine Policy* 97: 139–146. https://doi.org/10.1016/j.marpol.2018.06.001.

Blowes, S. A., S. R. Supp, L. H. Antão, et al. 2019. "The Geography of Biodiversity Change in Marine and Terrestrial Assemblages." *Science* 366, no. 6463: 339–345. https://doi.org/10.1126/science.aaw1620.

Bodin, Ö. 2017. "Collaborative Environmental Governance: Achieving Collective Action in Social-Ecological Systems." *Science* 357, no. 6352: eaan1114. https://doi.org/10.1126/science.aan1114.

Bottrill, M. C., and R. L. Pressey. 2012. "The Effectiveness and Evaluation of Conservation Planning." *Conservation Letters* 5, no. 6: 407–420. https://doi.org/10.1111/j.1755-263X.2012.00268.x.

Brockington, D. 2002. *Fortress Conservation: The Preservation of the Mkomazi Game Reserve, Tanzania*. Indiana University Press.

Brockington, D., and J. Igoe. 2006. "Eviction for Conservation: A Global Overview." *Conservation and Society* 4, no. 3: 424–470.

Bull, J. W., E. J. Milner-Gulland, P. F. E. Addison, et al. 2020. "Net Positive Outcomes for Nature." *Nature Ecology and Evolution* 4, no. 1: 4–7. https://doi.org/10.1038/s41559-019-1022-z.

Burke, K. D., J. W. Williams, M. A. Chandler, A. M. Haywood, D. J. Lunt, and B. L. Otto-Bliesner. 2018. "Pliocene and Eocene Provide Best Analogs for Near-Future Climates." *Proceedings of the National Academy of Sciences of the United States of America* 115, no. 52: 13288–13293. https://doi.org/10.1073/pnas.1809600115.

Büscher, B., and R. Fletcher. 2019. "Towards Convivial Conservation." *Conservation and Society* 17, no. 3: 283–296.

CBD. 2018. "Protected Areas and Other Effective Area-Based Conservation Measures (Decision 14/8)." https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf.

CBD. 2022. "COP15: Final Text of Kunming-Montreal Global Biodiversity Framework." https://www.cbd.int/article/cop15-final-text-kunming-montreal-gbf-221222.

Cheung, W. W. L., G. Reygondeau, and T. L. Frölicher. 2016. "Large Benefits to Marine Fisheries of Meeting the 1.5°C Global Warming Target." *Science* 354, no. 6319: 1591–1594. https://doi.org/10.1126/science.aag2331.

Clement, S., A. Guerrero Gonzalez, and C. Wyborn. 2020. "Understanding Effectiveness in Its Broader Context: Assessing Case Study Methodologies for Evaluating Collaborative Conservation Governance." *Society and Natural Resources* 33, no. 4: 462–483. https://doi.org/10.1080/08941920.2018.1556761.

Coad, L., A. Campbell, L. Miles, and K. Humphries. 2008. *The Costs and Benefits of Protected Areas for Local Livelihoods: A Review of the Current Literature*. UNEP World Conservation Monitoring Centre.

Corlett, R. T., and D. A. Westcott. 2013. "Will Plant Movements Keep Up With Climate Change?" *Trends in Ecology and Evolution* 28, no. 8: 482–488. https://doi.org/10.1016/j.tree.2013.04.003.

Crausbay, S. D., H. R. Sofaer, A. E. Cravens, et al. 2022. "A Science Agenda to Inform Natural Resource Management Decisions in an Era of Ecological Transformation." *Bioscience* 72, no. 1: 71–90. https://doi.org/10.1093/biosci/biab102.

Cumming, G. S., D. H. M. Cumming, and C. L. Redman. 2006. "Scale Mismatches in Social-Ecological Systems: Causes, Consequences, and Solutions." *Ecology and Society* 11, no. 1: 14.

Dawson, N., B. Coolsaet, E. Sterling, et al. 2021. "Ecology and Society: The Role of Indigenous Peoples and Local Communities in Effective and Equitable Conservation." *Ecology and Society* 26, no. 3: 19. https://doi.org/10.5751/ES-12625-260319.

Deléglise, H., D. Justeau-Allaire, M. Mulligan, et al. 2024. "Integrating Multi-Objective Optimization and Ecological Connectivity to Strengthen Peru's Protected Area System Towards the 30*2030 Target." *Biological Conservation* 299: 110799. https://doi.org/10.1016/j.biocon.2024.110799.

Dollo, M., P. K. Samal, R. Sundriyal, and K. Kumar. 2009. "Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalaya, India." *Journal of American Science* 5, no. 5: 41–52.

Domínguez, L., and C. Luoma. 2020. "Decolonising Conservation Policy: How Colonial Land and Conservation Ideologies Persist and Perpetuate Indigenous Injustices at the Expense of the Environment." *Land* 9, no. 3: 65. https://doi.org/10.3390/land9030065.

Donald, P. F., and A. D. Evans. 2006. "Habitat Connectivity and Matrix Restoration: The Wider Implications of Agri-Environment Schemes." *Journal of Applied Ecology* 43, no. 2: 209–218. https://doi.org/10.1111/j.1365-2664.2006.01146.x.

Dudley, N., and S. Alexander. 2017. "Agriculture and Biodiversity: A Review." *Biodiversity* 18, no. 2–3: 45–49. https://doi.org/10.1080/14888386.2017.1351892.

Dudley, N., H. Jonas, F. Nelson, et al. 2018. "The Essential Role of Other Effective Area-Based Conservation Measures in Achieving Big Bold Conservation Targets." *Global Ecology and Conservation* 15: e00424. https://doi.org/10.1016/j.gecco.2018.e00424.

Eken, G., L. Bennun, T. M. Brooks, et al. 2004. "Key Biodiversity Areas as Site Conservation Targets." *Bioscience* 54, no. 12: 1110–1118. https://doi.org/10.1641/0006-3568(2004)054[1110:KBAASC]2.0.CO;2.

Emerson, K., and T. Nabatchi. 2015. "Evaluating the Productivity of Collaborative Governance Regimes: A Performance Matrix." *Public Performance and Management Review* 38, no. 4: 717–747. https://doi.org/10.1080/15309576.2015.1031016.

Fa, J. E., J. E. Watson, I. Leiper, et al. 2020. "Importance of Indigenous Peoples' Lands for the Conservation of Intact Forest Landscapes." *Frontiers in Ecology and the Environment* 18, no. 3: 135–140. https://doi.org/10.1002/fee.2148.

Frumkin, H., G. N. Bratman, S. J. Breslow, et al. 2017. "Nature Contact and Human Health: A Research Agenda." *Environmental Health Perspectives* 125, no. 7: 075001. https://doi.org/10.1289/EHP1663.

Game, E. T., G. Lipsett-Moore, E. Saxon, N. Peterson, and S. Sheppard. 2011. "Incorporating Climate Change Adaptation Into National Conservation Assessments." *Global Change Biology* 17: 3150–3160.

Geisler, C. 2003. "A New Kind of Trouble: Evictions in Eden." *International Social Science Journal* 55, no. 175: 69–78.

Geisler, C., and R. De Sousa. 2001. "From Refuge to Refugee: The African Case." *Public Administration and Development* 21, no. 2: 159–170. https://doi.org/10.1002/pad.158.

Groves, C., and E. T. Game. 2016. *Conservation Planning: Informed Decisions for a Healthier Planet*. Roberts Publishers.

Gurney, G. G., E. S. Darling, G. N. Ahmadia, et al. 2021. "Biodiversity Needs Every Tool in the Box: Use OECMs." *Nature* 595, no. 7869: 646–649. https://doi.org/10.1038/d41586-021-02041-4.

Harris, R. M. B., L. J. Beaumont, T. R. Vance, et al. 2018. "Biological Responses to the Press and Pulse of Climate Trends and Extreme Events." *Nature Climate Change* 8, no. 7: 579–587. https://doi.org/10.1038/s41558-018-0187-9.

Hickling, R., D. B. Roy, J. K. Hill, R. Fox, and C. D. Thomas. 2006. "The Distributions of a Wide Range of Taxonomic Groups Are Expanding Polewards." *Global Change Biology* 12, no. 3: 450–455. https://doi.org/10.1111/j.1365-2486.2006.01116.x.

IPCC. 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 3056. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FullReport.pdf.

IPCC. 2023. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 35–115. IPCC.

Jacobs, L. A., S. P. Hazelwood, C. B. Avery, and C. Sangster-Biye. 2022. "Reimagining U.S. Federal Land Management Through Decolonization and Indigenous Value Systems." *Journal of Park and Recreation Administration* 40, no. 1: 1. https://doi.org/10.18666/JPRA-2021-10973.

Jayadevan, A., R. Nayak, K. K. Karanth, et al. 2020. "Navigating Paved Paradise: Evaluating Landscape Permeability to Movement for Large Mammals in Two Conservation Priority Landscapes in India." *Biological Conservation* 247: 108613. https://doi.org/10.1016/j.biocon.2020.108613.

Jonas, H. D., G. N. Ahmadia, H. C. Bingham, et al. 2021. "Equitable and Effective Area-Based Conservation: Towards the Conserved Areas Paradigm." *Parks* 27: 71–84.

Kauffman, M. J., F. Cagnacci, S. Chamaillé-Jammes, et al. 2021. "Mapping Out a Future for Ungulate Migrations." *Science* 372, no. 6542: 566–569. https://doi.org/10.1126/science.abf0998.

Keppel, G., K. P. Van Niel, G. W. Wardell-Johnson, et al. 2012. "Refugia: Identifying and Understanding Safe Havens for Biodiversity Under Climate Change." *Global Ecology and Biogeography* 21, no. 4: 393–404. https://doi.org/10.1111/j.1466-8238.2011.00686.x.

Kettlewell, P., R. Byrne, and S. Jeffery. 2023. "Wheat Area Expansion Into Northern Higher Latitudes and Global Food Security." *Agriculture, Ecosystems and Environment* 351: 108499. https://doi.org/10.1016/j.agee.2023.108499.

King, M., D. Altdorff, P. Li, L. Galagedara, J. Holden, and A. Unc. 2018. "Northward Shift of the Agricultural Climate Zone Under 21st-Century Global Climate Change." *Scientific Reports* 8, no. 1: 7904. https://doi.org/10.1038/s41598-018-26321-8.

Kirk, H., G. E. Garrard, T. Croeser, et al. 2021. "Building Biodiversity Into the Urban Fabric: A Case Study in Applying Biodiversity Sensitive Urban Design (BSUD)." *Urban Forestry and Urban Greening* 62: 127176. https://doi.org/10.1016/j.ufug.2021.127176.

Kiwango, W. A., and M. B. Mabele. 2022. "Why the Convivial Conservation Vision Needs Complementing to Be a Viable Alternative for Conservation in the Global South." *Conservation and Society* 20, no. 2: 179–189. https://doi.org/10.4103/cs.cs_45_21.

Krosby, M., D. M. Theobald, R. Norheim, and B. H. McRae. 2018. "Identifying Riparian Climate Corridors to Inform Climate Adaptation Planning." *PLoS One* 13, no. 11: e0205156.

Lafond, V., T. Cordonnier, and B. Courbaud. 2015. "Reconciling Biodiversity Conservation and Timber Production in Mixed Uneven-Aged Mountain Forests: Identification of Ecological Intensification Pathways." *Environmental Management* 56, no. 5: 1118–1133. https://doi.org/10.1007/s00267-015-0557-2.

Lapointe, N. W. R., S. J. Cooke, J. G. Imhof, et al. 2014. "Principles for Ensuring Healthy and Productive Freshwater Ecosystems That Support

Sustainable Fisheries." *Environmental Reviews* 22, no. 2: 110–134. https://doi.org/10.1139/er-2013-0038.

Lawler, J. J., D. D. Ackerly, C. M. Albano, et al. 2015. "The Theory Behind, and the Challenges of, Conserving Nature's Stage in a Time of Rapid Change." *Conservation Biology* 29, no. 3: 618–629. https://doi.org/10.1111/cobi.12505.

Lentz, D. R., and J. S. Christenson. 2011. "The Karner Blue Butterfly: Wisconsin's Statewide Habitat Conservation Plan." In *The Endangered Species Act and Federalism: Effective Conservation Through Greater State Commitment*, edited by K. Arha and B. H. Thompson Jr., 147–164. Routledge.

Lepczyk, C. A., M. F. Aronson, and F. A. La Sorte. 2023. "Cities as Sanctuaries." *Frontiers in Ecology and the Environment* 21, no. 5: 251–259. https://doi.org/10.1002/fee.2637.

Lindenmayer, D. B., and J. F. Franklin. 2002. *Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach*. Island Press.

Littlefield, C. E., M. Krosby, J. L. Michalak, and J. J. Lawler. 2019. "Connectivity for Species on the Move: Supporting Climate-Driven Range Shifts." *Frontiers in Ecology and the Environment* 17: 270–278.

Loos, J. 2021. "Reconciling Conservation and Development in Protected Areas of the Global South." *Basic and Applied Ecology* 54: 108–118. https://doi.org/10.1016/j.baae.2021.04.005.

Magris, R. A., R. L. Pressey, M. Mills, D. A. Vila-Nova, and S. Floeter. 2017. "Integrated Conservation Planning for Coral Reefs: Designing Conservation Zones for Multiple Conservation Objectives in Spatial Prioritisation." *Global Ecology and Conservation* 11: 53–68. https://doi.org/10.1016/j.gecco.2017.05.002.

Mahalwal, S., and A. Kabra. 2023. "The Slow Violence of Fortress Conservation Creates Conditions for Socially Unjust 'Voluntary' Relocation." *Biological Conservation* 286: 110264. https://doi.org/10.1016/j.biocon.2023.110264.

Margules, C. R., and R. L. Pressey. 2000. "Systematic Conservation Planning." *Nature* 405, no. 6782: 243–253.

Marnewick, D., C. Stevens, H. Jonas, R. Antrobus-Wuth, and N. Theron. 2021. "Assessing the Extent and Contribution of OECMs in South Africa." *Parks* 27, no. 1: 57–70.

Massarella, K., J. E. Krauss, W. Kiwango, and R. Fletcher. 2022. "Exploring Convivial Conservation in Theory and Practice: Possibilities and Challenges for a Transformative Approach to Biodiversity Conservation." *Conservation and Society* 20, no. 2: 59–68. https://doi.org/10.4103/cs.cs_53_22.

Masud, M. M., S. M. Shahabudin, A. Baskaran, and R. Akhtar. 2022. "Co-Management Approach to Sustainable Management of Marine Protected Areas: The Case of Malaysia." *Marine Policy* 138: 105010. https://doi.org/10.1016/j.marpol.2022.105010.

McIntyre, K. B., and C. A. Schultz. 2020. "Facilitating Collaboration in Forest Management: Assessing the Benefits of Collaborative Policy Innovations." *Land Use Policy* 96: 104683. https://doi.org/10.1016/j.landusepol.2020.104683.

McLaughlin, B. C., S. A. Skikne, E. Beller, et al. 2022. "Conservation Strategies for the Climate Crisis: An Update on Three Decades of Biodiversity Management Recommendations From Science." *Biological Conservation* 268: 109497. https://doi.org/10.1016/j.biocon.2022.109497.

Moilanen, A. 2007. "Landscape Zonation, Benefit Functions and Target-Based Planning: Unifying Reserve Selection Strategies." *Biological Conservation* 134, no. 4: 571–579.

Morelli, T. L., C. Daly, S. Z. Dobrowski, et al. 2016. "Managing Climate Change Refugia for Climate Adaptation." *PLoS One* 11, no. 8: e0159909. https://doi.org/10.1371/journal.pone.0159909.

Moreno-Rueda, G., J. M. Pleguezuelos, M. Pizarro, and A. Montori. 2012. "Northward Shifts of the Distributions of Spanish Reptiles in Association With Climate Change." *Conservation Biology* 26, no. 2: 278–283. https://doi.org/10.1111/j.1523-1739.2011.01793.x.

Muller, S. 2003. "Towards Decolonisation of Australia's Protected Area Management: The Nantawarrina Indigenous Protected Area Experience." *Australian Geographical Studies* 41, no. 1: 29–43. https://doi.org/10.1111/1467-8470.00190.

Naidoo, R., A. Balmford, R. Costanza, et al. 2008. "Global Mapping of Ecosystem Services and Conservation Priorities." *Proceedings of the National Academy of Sciences of the United States of America* 105, no. 28: 9495–9500. https://doi.org/10.1073/pnas.0707823105.

Neeson, T. M., M. C. Ferris, M. W. Diebel, P. J. Doran, J. R. O'Hanley, and P. B. McIntyre. 2015. "Enhancing Ecosystem Restoration Efficiency Through Spatial and Temporal Coordination." *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 19: 6236–6241. https://doi.org/10.1073/pnas.1423812112.

Nelson, G., J. Bogard, K. Lividini, et al. 2018. "Income Growth and Climate Change Effects on Global Nutrition Security to Mid-Century." *Nature Sustainability* 1, no. 12: 773–781. https://doi.org/10.1038/s41893-018-0192-z.

Nelson, F., P. Muyamwa-Mupeta, S. Muyengwa, E. Sulle, and D. Kaelo. 2021. "Progress or Regression? Institutional Evolutions of Community-Based Conservation in Eastern and Southern Africa." *Conservation Science and Practice* 3, no. 1: e302. https://doi.org/10.1111/csp2.302.

Nuñez, T. A., J. J. Lawler, B. H. McRae, et al. 2013. "Connectivity Planning to Address Climate Change." *Conservation Biology* 27, no. 2: 407–416. https://doi.org/10.1111/cobi.12014.

Ossola, A., D. Locke, B. Lin, and E. Minor. 2019. "Yards Increase Forest Connectivity in Urban Landscapes." *Landscape Ecology* 34, no. 12: 2935–2948. https://doi.org/10.1007/s10980-019-00923-7.

Pecl, G. T., M. B. Araújo, J. D. Bell, et al. 2017. "Biodiversity Redistribution Under Climate Change: Impacts on Ecosystems and Human Well-Being." *Science* 355, no. 6332: eaai9214. https://doi.org/10.1126/science.aai9214.

Pinsky, M. L., B. Worm, M. J. Fogarty, J. L. Sarmiento, and S. A. Levin. 2013. "Marine Taxa Track Local Climate Velocities." *Science* 341: 1239–1242.

Prado, D. S., C. S. Seixas, and M. Trimble. 2022. "Catalytic and Structural Factors Behind Advancements of Co-Management in Protected Areas: Contributions for Its Evaluation." *Journal of Environmental Management* 311: 114825. https://doi.org/10.1016/j.jenvman.2022.114825.

Pressey, R. L., P. Visconti, M. C. McKinnon, et al. 2021. "The Mismeasure of Conservation." *Trends in Ecology and Evolution* 36, no. 9: 808–821. https://doi.org/10.1016/j.tree.2021.06.008.

Purwanto, Y., H. Nugroho, A. S. Achmadi, and E. Munawaroh. 2020. "Biosphere Reserve Concept Implementation for Creating Sustainability." *Journal of Tropical Ethnobiology* 3, no. 1: 43–56. https://doi.org/10.46359/jte.v3i1.7.

Ramankutty, N., J. A. Foley, J. Norman, and K. McSweeney. 2002. "The Global Distribution of Cultivable Lands: Current Patterns and Sensitivity to Possible Climate Change." *Global Ecology and Biogeography* 11, no. 5: 377–392. https://doi.org/10.1046/j.1466-822x.2002.00294.x.

Reside, A. E., N. Butt, and V. M. Adams. 2018. "Adapting Systematic Conservation Planning for Climate Change." *Biodiversity and Conservation* 27, no. 1: 1–29. https://doi.org/10.1007/s10531-017-1442-5.

Reyers, B., P. J. O'Farrell, J. L. Nel, and K. Wilson. 2012. "Expanding the Conservation Toolbox: Conservation Planning of Multifunctional Landscapes." *Landscape Ecology* 27, no. 8: 1121–1134. https://doi.org/10.1007/s10980-012-9761-0.

Ribeiro, M. P., K. de Mello, and R. A. Valente. 2022. "How Can Forest Fragments Support Protected Areas Connectivity in an Urban Landscape in Brazil?" *Urban Forestry & Urban Greening* 74: 127683. https://doi.org/10.1016/j.ufug.2022.127683.

Ross, H., C. Grant, C. J. Robinson, A. Izurieta, D. Smyth, and P. Rist. 2009. "Co-Management and Indigenous Protected Areas in Australia: Achievements and Ways Forward." *Australasian Journal of Environmental Management* 16, no. 4: 242–252. https://doi.org/10.1080/14486563.2009.9725240.

SANBI. 2018. "National Biodiversity Assessment 2018: The Status of South Africa's Ecosystems and Biodiversity." Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries.

Schleicher, J., C. A. Peres, T. Amano, W. Llactayo, and N. Leader-Williams. 2017. "Conservation Performance of Different Conservation Governance Regimes in the Peruvian Amazon." *Scientific Reports* 7, no. 1: 11318. https://doi.org/10.1038/s41598-017-10736-w.

Schloss, C. A., T. A. Nuñez, and J. J. Lawler. 2012. "Dispersal Will Limit Ability of Mammals to Track Climate Change in the Western Hemisphere." *Proceedings of the National Academy of Sciences of the United States of America* 109: 8606–8611.

Schuster, R., R. Buxton, J. O. Hanson, et al. 2023. "Protected Area Planning to Conserve Biodiversity in an Uncertain Future." *Conservation Biology* 37, no. 3: e14048. https://doi.org/10.1111/cobi.14048.

Sengupta, A., M. Bhan, S. Bhatia, A. Joshi, S. Kuriakose, and K. S. Seshadri. 2024. "Realizing "30 ×30" in India: The Potential, the Challenges, and the Way Forward." *Conservation Letters* 17, no. 2: e13004. https://doi.org/10.1111/conl.13004.

Shah, S. H., and L. Rodina. 2018. "Water Ethics, Justice, and Equity in Social-Ecological Systems Conservation: Lessons From the Queensland Wild Rivers Act." *Water Policy* 20, no. 5: 933–952. https://doi.org/10.2166/wp.2018.016.

Smith, J. A., T. P. Duane, and C. C. Wilmers. 2019. "Moving Through the Matrix: Promoting Permeability for Large Carnivores in a Human-Dominated Landscape." *Landscape and Urban Planning* 183: 50–58. https://doi.org/10.1016/j.landurbplan.2018.11.003.

Sumaila, U. R., C. Bellmann, and A. Tipping. 2016. "Fishing for the Future: An Overview of Challenges and Opportunities." *Marine Policy* 69: 173–180. https://doi.org/10.1016/j.marpol.2016.01.003.

Tingley, M. W., M. S. Koo, C. Moritz, A. C. Rush, and S. R. Beissinger. 2012. "The Push and Pull of Climate Change Causes Heterogeneous Shifts in Avian Elevational Ranges." *Global Change Biology* 18, no. 11: 3279–3290. https://doi.org/10.1111/j.1365-2486.2012.02784.x.

Tran, T. C., N. C. Ban, and J. Bhattacharyya. 2020. "A Review of Successes, Challenges, and Lessons From Indigenous Protected and Conserved Areas." *Biological Conservation* 241: 108271. https://doi.org/10.1016/j.biocon.2019.108271.

Tscharntke, T., I. Grass, T. C. Wanger, C. Westphal, and P. Batáry. 2021. "Beyond Organic Farming – Harnessing Biodiversity-Friendly Landscapes." *Trends in Ecology and Evolution* 36, no. 10: 919–930. https://doi.org/10.1016/j.tree.2021.06.010.

Tucker, M. A., K. Böhning-Gaese, W. F. Fagan, et al. 2018. "Moving in the Anthropocene: Global Reductions in Terrestrial Mammalian Movements." *Science* 359, no. 6374: 466–469. https://doi.org/10.1126/science.aam9712.

UNESCO. 2021. *Technical Guidelines for Biosphere Reserves*, 126. UNESCO Man and Biosphere Programme. https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.unesco.it/wp-content/uploads/2023/11/technical-guidelines-2021.pdf&ved=2ahUKEwj5mq3orJOIAxVoFTQIHT_JBpMQFnoECB0QAQ&usg=AOvVaw3ki01sLLT78-Fs4MawIbEU.

USDOI. 2021. "Joint Secretarial Order 3403 on Fulfilling the Trust Responsibility to Indian Tribes in the Stewardship of Federal Lands and Waters." https://www.doi.gov/media/document/joint-secretarial-order-3403.

Van Cuong, C., P. Dart, and M. Hockings. 2017. "Biosphere Reserves: Attributes for Success." *Journal of Environmental Management* 188: 9–17. https://doi.org/10.1016/j.jenvman.2016.11.069.

Vickery, J. A., R. B. Bradbury, I. G. Henderson, M. A. Eaton, and P. V. Grice. 2004. "The Role of Agri-Environment Schemes and Farm Management Practices in Reversing the Decline of Farmland Birds in England." *Biological Conservation* 119, no. 1: 19–39. https://doi.org/10.1016/j.biocon.2003.06.004.

Visseren-Hamakers, I. J., P. Leroy, and P. Glasbergen. 2012. "Conservation Partnerships and Biodiversity Governance: Fulfilling Governance Functions Through Interaction." *Sustainable Development* 20, no. 4: 264–275. https://doi.org/10.1002/sd.482.

Wallingford, P. D., T. L. Morelli, J. M. Allen, et al. 2020. "Adjusting the Lens of Invasion Biology to Focus on the Impacts of Climate-Driven Range Shifts." *Nature Climate Change* 10, no. 5: 398–405. https://doi.org/10.1038/s41558-020-0768-2.

Ward, M., S. Saura, B. Williams, et al. 2020. "Just Ten Percent of the Global Terrestrial Protected Area Network Is Structurally Connected via Intact Land." *Nature Communications* 11, no. 1: 4563. https://doi.org/10.1038/s41467-020-18457-x.

Watson, J. E. M., R. Venegas-Li, H. Grantham, et al. 2023. "Priorities for Protected Area Expansion so Nations Can Meet Their Kunming-Montreal Global Biodiversity Framework Commitments." *Integrative Conservation* 2, no. 3: 140–155. https://doi.org/10.1002/inc3.24.

Wiens, J. J. 2016. "Climate-Related Local Extinctions Are Already Widespread Among Plant and Animal Species." *PLoS Biology* 14, no. 12: e2001104.

Wilson, E. O. 2016. *Half-Earth: Our Planet's Fight for Life*. W. W. Norton & Company.

Wintle, B. A., H. Kujala, A. Whitehead, et al. 2019. "Global Synthesis of Conservation Studies Reveals the Importance of Small Habitat Patches for Biodiversity." *Proceedings of the National Academy of Sciences of the United States of America* 116, no. 3: 909–914. https://doi.org/10.1073/pnas.1813051115.

Wu, J. X., C. B. Wilsey, L. Taylor, and G. W. Schuurman. 2018. "Projected Avifaunal Responses to Climate Change Across the U.S. National Park System." *PLoS One* 13, no. 3: e0190557. https://doi.org/10.1371/journal.pone.0190557.

Wyborn, C., and R. P. Bixler. 2013. "Collaboration and Nested Environmental Governance: Scale Dependency, Scale Framing, and Cross-Scale Interactions in Collaborative Conservation." *Journal of Environmental Management* 123: 58–67. https://doi.org/10.1016/j.jenvman.2013.03.014.

Xu, C., T. A. Kohler, T. M. Lenton, J.-C. Svenning, and M. Scheffer. 2020. "Future of the Human Climate Niche." *Proceedings of the National Academy of Sciences of the United States of America* 117, no. 21: 11350–11355. https://doi.org/10.1073/pnas.1910114117.

Zabala, A., I. Palomo, M. Múgica, and C. Montes. 2024. "Challenges Beyond Reaching a 30% of Area Protection." *Npj Biodiversity* 3, no. 1: 9. https://doi.org/10.1038/s44185-024-00041-x.

Zabel, F., B. Putzenlechner, and W. Mauser. 2014. "Global Agricultural Land Resources – A High Resolution Suitability Evaluation and Its Perspectives Until 2100 Under Climate Change Conditions." *PLoS One* 9, no. 9: e107522. https://doi.org/10.1371/journal.pone.0107522.

Zafra-Calvo, N., E. Garmendia, U. Pascual, et al. 2019. "Progress Toward Equitably Managed Protected Areas in Aichi Target 11: A Global Survey." *Bioscience* 69, no. 3: 191–197. https://doi.org/10.1093/biosci/biy143.

Zeng, Y. W., L. P. Koh, and D. S. Wilcove. 2022. "Gains in Biodiversity Conservation and Ecosystem Services From the Expansion of the Planet's Protected Areas." *Science Advances* 8, no. 22: eabl9885. https://doi.org/10.1126/sciadv.abl9885.

Zhang, J., N. Yin, S. Wang, J. Yu, W. Zhao, and B. Fu. 2020. "A Multiple Importance–Satisfaction Analysis Framework for the Sustainable Management of Protected Areas: Integrating Ecosystem Services and Basic Needs." *Ecosystem Services* 46: 101219. https://doi.org/10.1016/j.ecoser.2020.101219.

Zhao, C., B. Liu, S. Piao, et al. 2017. "Temperature Increase Reduces Global Yields of Major Crops in Four Independent Estimates." *Proceedings of the National Academy of Sciences of the United States of America* 114, no. 35: 9326–9331. https://doi.org/10.1073/pnas.1701762114.