Considerations for biodiversity conservation in the Anthropocene

A STAP information note
November 2025

STAP SCIENTIFIC AND TECHNICAL ADVISORY PANEL
An independent group of scientists that advises the Global Environment Facility

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ABOUT STAP:
The Scientific and Technical Advisory Panel (STAP) comprises seven expert advisors supported by a Secretariat, who are together responsible for connecting the Global Environment Facility to the most up-to-date, authoritative, and globally representative science. stapgef.org. The STAP Secretariat is hosted by the United Nations Environment Programme (UNEP).

ABOUT GEF:
The Global Environment Facility (GEF) was established on the eve of the 1992 Rio Earth Summit to help tackle our planet's most pressing environmental challenges. Since then, the GEF has provided more than 22 billion US dollars in grants and blended finance and mobilized over 120 billion US dollars in co-financing for more than 5,000 national and regional projects and programmes that generate global environmental benefits. The GEF partnership brings together 186 member governments with international institutions, civil society, Indigenous Peoples, and the private sector to address global environmental issues and support sustainable development. thegef.org

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CONTENTS

1. EXECUTIVE SUMMARY

Human activities are driving rapid and profound transformations across the Earth system. In this Anthropocene period,[1] ecosystems are shifting in ways that make traditional conservation approaches, based on stable historical baselines, less effective. Protected areas and restoration efforts can no longer be designed as if biodiversity or ecological conditions will remain constant over time. As the Global Environment Facility (GEF) moves into GEF-9 and expands its support for the Global Biodiversity Framework, ensuring that investments remain impactful under accelerating climate and ecological change is essential.

The issue and why it matters for the GEF

Across the terrestrial biosphere, more than half of ecosystems, including many Key Biodiversity Areas (KBAs), now exhibit novel species assemblages and functions. Tropical forests and coral reefs, two globally significant biodiversity systems, are especially vulnerable to new climatic regimes. Many climate refugia[2] remain unprotected, and restoration efforts often struggle when they aim to recreate ecological states that are no longer feasible.

Climate change, species loss, and land-use transformation interact to reshape ecosystems in unpredictable ways. Conservation effectiveness increasingly depends on maintaining functional landscapes, enabling species movement, and supporting ecosystem services even as ecological composition shifts. This requires moving beyond fragmented or historically oriented approaches and toward strategies that sustain resilience at landscape and seascape scales.

These dynamics, unless considered in biodiversity investments, pose direct challenges to effectiveness and durability of global environmental benefits and require conservation approaches that explicitly acknowledge and manage change. Defining current novel conditions, as well as possible futures based on key trends in major global change drivers, such as climate change, and identifying appropriate response options now and for the future can help ensure the resilience and durability of GEF investments in biodiversity.

STAP recommendations

1. **Increase connectivity, going beyond individual migration corridors, to manage large-scale conservation mosaics for landscape permeability.** GEF investments need to strengthen ecological connectivity (links between particular habitat patches that facilitate the movement of species between areas) by supporting conservation mosaics[3] that integrate protected areas, community lands, and productive landscapes. This approach improves landscape permeability, helps address climate-driven range shifts, and enables coordinated management across jurisdictions.
2. **Identify and protect climate change refugia.** Prioritizing KBAs and ecosystems that are naturally buffered from climate impacts is essential to securing long-term ecosystem function and biodiversity resilience. Both terrestrial and marine refugia, particularly in tropical forests and coral reefs, should be incorporated into protected and conserved area networks. The GEF needs to closely monitor and integrate emerging science on climate refugia into its investments, as this has significant potential to improve productivity, livelihoods, and buffering from extreme events.

1 Anthropocene refers to the current period of planetary transformation driven primarily by human activities and is characterized by extensive and increasing rates of change across all components of the Earth system, including its interconnected physical, ecological, and social subsystems.

2 Climate refugia or safe havens are areas that are relatively buffered from climate change and therefore remain more stable than their surrounding landscape. They enable biodiversity and sociocultural values to persist and are therefore critical for biodiversity conservation.

3 Conservation mosaics are large, multi-jurisdictional landscapes and seascapes with collaborative governance to coordinate planning, facilitate co-management, and promote environmental justice.

3. **Explicitly consider the climate change dimension for maintaining and restoring ecosystem services.** Restoration efforts may be more effective if if focusing on sustaining ecosystem functions and services under current and future climate conditions rather than on recreating historical states. Aligning restoration with biodiversity, climate adaptation, and mitigation goals under the Rio Conventions, rather than implementing projects for each convention separately, can enhance effectiveness in addressing multiple stresses and be more cost-effective.

To sum up, in an increasingly dynamic and uncertain world conservation efforts need to shift from preserving static ecosystems to managing continual change. By incorporating emerging science on ecosystem and climate novelty, connectivity, climate refugia, and functional restoration, the GEF can ensure that GEF-9 investments effective and durable global environmental benefits while supporting resilient communities and ecosystems.

2. THE UNDERLYING ISSUE AND WHY IT MATTERS FOR THE GEF

A fundamental assumption underlying traditional biodiversity conservation is that if an area is protected from habitat loss and resource extraction, then biodiversity and relevant environmental conditions will remain constant in space and over time. Historically, based on this assumption, protected areas (PAs) and other effective area-based conservation measures (OECMs)[4] were created and managed with the implicit objective of maintaining a historic reference state.[5] Similarly, many ecological restoration projects and activities (e.g. reforestation, afforestation, and rehabilitation of degraded ecosystems) seek to restore a site to historic ecosystem conditions or reference states.[6] However, in much of the world today, that assumption is no longer valid. In the current period shaped by human impact – the Anthropocene (Box 1) – management strategies that rely on stable historical baselines for ecosystems or species are decreasingly viable, given ongoing environmental changes and uncertainties.

Instead, biodiversity policies and management approaches – such as those applied through Global Environment Facility (GEF)-financed projects – need to explicitly recognize ongoing, directional environmental change, including ecosystem transformations, which can be gradual, fast, or abrupt.[7]

As well, projects need to continue to ensure that ecosystem services are maintained, even though ecosystem structure and composition may change.[8]

Designating PAs has long been central to global biodiversity conservation,[9] yet with climate change, it is increasingly recognized that relying solely on protected areas – even if well managed – is not enough to safeguard biodiversity in the long-term.[10]

4 An OECM is a geographically defined area other than a PA that is governed and managed in ways that achieve positive long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and, where applicable, cultural, spiritual, socioeconomic, and other locally relevant values (CBD 2018).

5 Arcese & Sinclair 1997.

6 Harris et al. 2006.

7 Williams et al. 2021.

8 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report, restoration defines restoration as any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state. In its paper on nature-based solutions, the STAP concluded, "There cannot be resilient futures without NbS (nature-based solutions) that focus on protecting, managing and restoring ecosystems and the services they provide" (Bierbaum 2020).

9 Soulé 1991; Maxwell, et al. 2020.

10 Soulé 1991; Maxwell, et al. 2020.

The GEF has provided the largest source of funding for biodiversity conservation – including for PAs – worldwide, having invested in more than 2,500 million hectares of terrestrial and marine PAs across the globe.[11] The GEF has also made significant investments in programs and projects to restore degraded ecosystems, often in the form of cross-cutting initiatives combining biodiversity conservation and land management actions.[12]

As it begins its ninth programming phase (2026–30, GEF-9), the GEF – including its management of the Global Biodiversity Framework Fund (GBFF) – is enhancing its deep commitment to biodiversity conservation. In the context of global change, to ensure the GEF's investments continue to be effective and durable, approaches to biodiversity conservation, including PAs and restoration, are being reconsidered. Successfully delivering global environmental benefits (GEBs) requires more than incremental change; a paradigm shift in applied science, policy, and practice is needed.[13] This includes considering current and future climate change when setting conservation priorities, including managing and restoring ecological connectivity, protecting KBAs that are "safe havens" or "refugia" where species may be buffered from climate change impacts, and ensuring that ecosystem services that underpin the quality of life are sustained.

11 See https://www.thegef.org/what-we-do/topics/biodiversity.

12 GEF 2022; GEF 2025.

13 Archer et al. 2025.

Photo: iStock

Box 1: The Anthropocene – why it matters for biodiversity conservation

The Anthropocene (the current period of planetary transformation driven primarily by human impacts) is characterized by ***extensive and increasing rates of change across all components of the Earth system, including its interconnected physical, ecological, and social subsystems.***[14] The intensity of these human-induced impacts creates both climatic conditions and species assemblages that have no comparison within the last 50 million years[15] (hereafter referred to as "novel conditions" or "novel ecosystems").[16] The specific drivers and impacts of novelty are highly variable among ecosystems, and different configurations and intensities of drivers interact across spatial scales.[17] For example, three key drivers of global change create novel ecological conditions: climate change,[18] defaunation (loss of animal species),[19] and floristic disruption (loss of plant species).[20] These drivers interact; for example, climate-driven changes affect ecosystem responses to biological change[21] (e.g. responses to pest or disease outbreaks)[22] and lead to loss of mutualistic relationships, e.g. when increased sea surface temperature causes coral bleaching (the loss of algae from coral).[23] Loss of large-bodied animals, a type of defaunation,[24] impacts the resistance of ecosystems to invasive species[25] and the ability of ecosystems to provide ecosystem services, such as storing carbon. There is now a large body of scientific evidence[26] indicating that ecosystems and environments– even in remote areas – are "shifting from historical baselines that are generally observable, knowable, and agreed on to non-stationary conditions that are novel, uncertain, and contested".[27]

The Scientific and Technical Advisory Panel (STAP) to the GEF has outlined key principles to make projects and programs addressing environmental challenges, including biodiversity loss, more robust and durable in the face of global change. These principles include applying systems thinking with a clear theory of change, engaging the right stakeholders, ensuring robustness to future change, being explicit about behavioral drivers, pursuing integrated multi-benefit outcomes, fostering innovation (with an appropriate risk appetite), planning for scaling and transformation, and instituting continual learning and adaptive management.

As global change proceeds, successful biodiversity projects must address root causes and account for both current and future risks, not just address symptoms, to achieve lasting impact. In this information note, STAP provides a short overview of considerations for biodiversity conservation, based on a synthesis of the latest science. It summarizes why, in the context of a rapidly changing planet, traditional conservation approaches will prove

14 Steffen et al. 2017; Steffen et al. 2015; Steinbauer et al. 2018.
15 Burke et al. 2018, Masson-Delmotte, V. . 2023.
16 Radeloff et al. 2015.
17 Kerr et al. 2025.
18 Climate change was measured as the degree to which modern climate conditions are unprecedented, using the most recent 300-year period where a climatic variable was fully outside the modern range (1980-2019).
19 Defaunation was measured as the loss of mammalian species richness and changes in body size within the mammalian community, primarily as a result of human influence (Farby et al.2018, Svenning et al. 2024).
20 Floral disruption was measured as (a) the proportion of the species in an area that are alien.
21 Williams et al. 2021.
22 Raffa et al. 2013.
23 Hughes et al. 2018.
24 Defaunation is a type of global change, defined as the decrease and annihilation of wild animals from natural systems (Jerozolimski et al. 2003; Peres et al. 2007; Young et al. 2016).
25 Mungi et al. 2023.
26 Chapin et al. 2023; Folk et al. 2010; Ingeman et al. 2019; Coop et al. 2020; Thomas et al. 2020; Kerr et al. 2025.
27 Magness et al. 2022.

inadequate and could undermine the delivery of GEBs and the Global Biodiversity Framework (GBF) targets. Although important gaps remain in understanding how global change affects biodiversity – particularly the complex interactions among multiple stressors and across different scales – it is clear that new climate conditions and novel ecosystems have implications for biodiversity conservation and restoration. It is, therefore, essential to consider these factors and their implications now to achieve effective and lasting conservation outcomes (See Annex 1 for a non-exhaustive list of resources to help with biodiversity management and restoration.).

2.1. NEW CLIMATE CONDITIONS

More than half (58%) of the terrestrial biosphere, including existing PAs and KBAs,[28] have been dramatically altered by human actions – both directly (e.g. through land-use change, overexploitation, and introduced invasive species) and indirectly (e.g., through differential species responses to climate change). Many of these areas are now considered "novel" ecosystems.[29,30] KBAs are sites of global significance for biodiversity, including threatened and range-restricted species.[31] Goals A and B of the GBF (and especially GBF Target 3), as well as the GEF biodiversity focal area, specifically recognize KBAs as a priority for the expansion of PAs and OECMs in GEF-9.[32] The proposed strategy for the biodiversity focal area in GEF-9 recommends using the KBA standard to identify and prioritize areas for biodiversity conservation in GEF projects, although other similar criteria, if well justified, also are accepted.

Novel ecosystems are those where species composition, relative abundances, interactions, and/or ecosystem functions[33] have no historical precedent. Such areas may have crossed a threshold, precluding their return to a state before significant human modification, and now maintain their novel characteristics.[34] Novel ecosystems can develop in response to changes in human populations,[35] human-driven extinctions and extirpations (the complete removal of a species from a specific region),[36] introductions of non-native species,[37] direct exploitation of natural resources,[38] and land abandonment and afforestation.[39] As mentioned in Box 1,[40] three drivers contribute to creating novel ecological conditions: climate change, defaunation (loss or extinction of animals),[41] and floristic disruption (disruption of plant communities).[42] Local novel conditions in terrestrial systems are mainly driven by climate change and defaunation. However, in South Africa, Central Asia, and parts of Oceania, hotspots of novelty driven primarily by floristic disruption have been identified.[43]

Novel ecosystems and climates can potentially undermine the effectiveness of KBAs as a conservation prioritization tool,[44] since the current KBA standards assume that, if protected, species and ecosystems can remain stable in space and over time. Tropical forest species are at especially high risk from the novel climate conditions occurring

28 KBAs are globally significant sites for the persistence of biodiversity and are identified based on an International Union for Conservation of Nature global standard that includes 11 quantitative criteria developed in 2016. A global standard for the identification of key biodiversity areas.

29 Trew et al. 2024(b); Kerr et al. 2025.

30 Hobbs et al. 2013.

31 A global standard for the identification of key biodiversity areas.

32 Draft GEF-9 Programming Directions.

33 Graham et al. 2014.

34 Hobbs et al. 2006; Ordonez & Gill 2024 ; Kerr et al. 2025.

35 Radeloff et al. 2015.

36 Berti & Svenning 2020; Svenning et al. 2024.

37 Fehr et al. 2020; Walentowitz et al. 2023.

38 Jaureguiberry et al. 2022.

39 Shaffer et al. 2012.

40 Kerr et al. 2025.

41 Measured as the loss of large-bodied mammals.

42 Measured as the proportion of alien species and the intactness of the local plant community, as measured by changes in the abundance of native species, both of which are important for ecosystem structure and function.

43 Novel ecosystems also occur in marine ecosystems, including in intertidal rocky shores, tropical and temperate reefs, estuaries, and pelagic systems; however, less is known about their extent and impacts than in terrestrial systems.

44 Araujo et al. 2011; Dobrowski et al. 2021; Trew et al. 2024(a); Trew et al. 2024(b).

today[45] because they have evolved under a narrow range of thermal conditions and may only be able to tolerate a small margin of warming above their thermal optima.[46] This is of particular concern for conservation because tropical forests contain most of the world's biodiversity[47] and represent some of the largest remaining areas of high-integrity forest globally. Coral reefs are also hotspots of biodiversity and are at risk from climate change (Box 2). Recently, data[48] from several thousand tropical forest locations globally, over 30 years were analyzed to identify forests at highest risk from climate change and those that serve as climate refugia or safe havens.[49] The results reinforce the findings[50] that novel climate regimes are already widespread throughout tropical forest KBAs, with almost 60% of such KBAs exhibiting climate novelty.

The proportion of KBAs in Africa (76%) and Latin America (61%) with novel climates is particularly high. KBAs in the Central Congo Basin moist forests in the Democratic Republic of the Congo have novel climates, including in Salonga National Park, Africa's largest tropical forest PA. KBAs in the tropical Andes are notably affected by novel climates, as are those in Colombia, Ecuador, Panama, and the Bolivarian Republic of Venezuela. Globally, only 46% of tropical forest KBAs that serve as climate refugia have PA coverage over at least half their area, and 16% of these remain completely unprotected. In Asia and Oceania, 26% of climate refugia in tropical forest KBAs have at least 50% of their area within PAs, while 16% are unprotected. To summarize, many tropical forest KBAs are climatically stable and function as climate refugia, but they require increased protection.

45 Senior et al. 2019; Dobrowski et al. 2021; Trew et al. 2024.
46 Tewksbury et al. 2008; Trew & Maclean 2021; Jirinec et al. 2022.
47 Pillay et al. 2022; Crowe et al. 2023.
48 Trew et al. 2024(a).
49 Ashcroft 2010.
50 Kerr et al. 2025.

Photo: UNDP

Box 2: Identifying and protecting climate-resilient coral reefs

Coral reefs are hotspots of biodiversity and provide ecosystem services – e.g., food, tourism – to nearly 1 billion people. These important ecosystems are now in crisis, under pressure from warming oceans and the degradation of coral reef ecosystems due to overfishing, pollution, and coastal development. This creates an urgent need to safeguard coral reef refugia and sustain the communities that depend on them.

Recent science proposes three major categories of coral reef refugia from exposure to high ocean temperatures and other consequences of climate change avoidance, resistance, and recovery.[51] Although there has been a disproportionate focus on conserving avoidance refugia (corals that exist in stable and cooler water temperatures),[52] this framework offers an opportunity to enhance strategic reef conservation by creating a more diversified risk-spreading portfolio that also includes ecological resistance and coping with climate change.[53] Further, an expanded set of metrics for identifying and prioritizing high-integrity coral reef refugia is needed, including, not only excess heat metrics, but also environmental, ecological, and life-history variables.[54] The Wildlife Conservation Society and partners have developed the 2025–2030 Coral Reef Conservation Strategy to identify and protect a portfolio of Earth's most climate-resilient reefs with the aim of maintaining biodiversity and supporting coastal communities, and working towards the GBF goals and targets. The World Wildlife Fund-led GEF-7 Coral Reef Rescue project is also prioritizing the conservation of climate-resilient coral reefs in seven countries.

MERMAID AI: Using artificial intelligence to accelerate coral reef conservation

MERMAID (Marine Ecological Research Management Aid) is a free, open-source, cloud-based platform that helps scientists, reef managers, communities, and governments quickly identify and prioritize climate-resilient coral reefs and monitor the effectiveness of existing conservation efforts. It is currently used by more than 100 organizations in 53 countries. In 2025, MERMAID launched an artificial intelligence (AI) model for classifying coral reef photos that can automatically identify major reef benthic groups and hard coral genera to assess key metrics of coral reef ecological integrity. Recently, the Wildlife Conservation Society was one of 15 organizations to receive new support from the Bezos Earth Fund AI for Climate and Nature initiative, a 100 million US dollars initiative to accelerate climate and nature solutions by funding innovative approaches that leverage modern AI to deliver greater speed, scale, accuracy, and precision. Support from the Bezos Earth Fund will enable the Wildlife Conservation Society to expand AI to scale MERMAID in more than 50 countries, integrating global citizen science apps, developing an open-source AI model to automate the identification of more than 100 coral species, and creating real-time maps of climate-resilient reefs. These tools will empower local scientists, communities, and governments with data to protect reefs that sustain coastal livelihoods, fisheries, biodiversity, and climate adaptation.

51 McClanahan et al. 2023.

52 50 Reefs Landscape Assessment.

53 Anthony et al. 2020; Camp 2022; Chollett et al. 2022; Hoegh-Guldberg et al. 2018; McClanahan & Azali 2021; Beyer et al. 2018.

54 McClanahan 2025.

Two overarching needs for conservation emanate from the rapid changes occurring in the Anthropocene:

a. **Design and prioritize conservation interventions that explicitly consider changing and novel systems.** GEF programs and projects that aim to achieve biodiversity conservation would benefit from going beyond climate risk screening and ensuring robustness to current and future change. Projects will need to *explicitly consider the implications of novel ecosystems and climates* for project design and for sustaining ecosystem services in the context of global change. This means considering co-benefits that are essential for biodiversity conservation, such as alternative and resilient livelihoods, which can enable local communities to collectively invest more resources (e.g., time, labor, money) in sustainable land management practices.

   In particular, STAP suggests that projects setting priorities based on the KBA standard or existing PAs explicitly consider whether the target areas have already been irreversibly altered to novel ecosystems (through land-use change, restoration, introduced alien species, and/or climate change) or whether they appear to be stable. Solutions for dealing with the increase of novel conditions should focus on ecosystem conditions that promote resilience, function, and biodiversity, such as rewilding (especially restoring large animals, which has benefits for plant communities and natural food chains).[55] Examples of GEF investments requiring consideration of novel ecosystems include biodiversity focal area projects; the Critical Forest Biomes, Drylands and Drought Management, Wildlife Conservation for Development, Food Systems, Blue and Green Islands, and Sustainable Cities Integrated Programs (IPs); and other programs in GEF-9 targeting biodiversity and ecosystems.

b. **Mobilize long-term funding to support ecosystem resilience to change.** Many GEF programs have been working to conserve ecosystems and biodiversity. Public-private partnerships be effective for mobilizing long-term funding for biodiversity management within and outside of currently protected and conserved areas. This can be accomplished through the expansion of programs such as Project Finance for Permanence (PFP)[56] or the Legacy Landscapes Fund, with funding horizons ranging from 10 to more than 50 years. The GEF has invested in Enduring Earth, a PFP with coordinated funding from several donors, resulting in long-term funding commitments in several countries, including Gabon (10 years), Namibia (20 years), and the Eastern Tropical Pacific Marine Corridor (10 years).

55 Svenning et al. 2024.

56 Project finance for permanence is an innovative, sustainable finance mechanism that brings together stewards of a place to co-create and secure long-term funding and resources for conservation projects, ensuring they are well-managed and benefit local communities and achieve tangible, measurable environmental and socioeconomic benefits. The approach brings together governments, civil society, and donors to create a durable foundation for conservation efforts. See, for example, Enduring Earth; Cabrera et al. 2021.

3. STAP RECOMMENDATIONS

STAP recommends three specific areas for GEF-9 focus that explicitly address the implications of novel conditions, both expected and unexpected, from global change:

a. **Increase connectivity, going beyond migration corridors to manage large-scale conservation mosaics for landscape permeability.** Conservation mosaics are complex, socio-ecological systems: large, multi-jurisdictional landscapes and seascapes with collaborative governance to coordinate planning, facilitate co-management, and promote environmental justice. Ecological connectivity has become a core priority for achieving global biodiversity goals, including GBF Targets 2 and 3 (restoration and expanding networks of PAs and OECMs). See Boxes 4 and 5 for illustrative examples.

   Well-connected ecosystems are crucial for maintaining ecological and evolutionary processes, especially in the context of climate and other environmental change. Ecological connectivity refers to links between particular habitat patches that facilitate the movement of species between areas (e.g., via corridors).[57] Despite GBF Target 3 stipulating that the expanded network of PAs, OECMs, and Indigenous and Traditional Territories needs to be well connected, terrestrial, freshwater, and marine PA networks currently have limited connectivity: Only about 10% of the world's terrestrial PAs are structurally connected.[58]

   In GEF-8, through the Amazon Sustainable Landscapes Program and the Global Wildlife Program/Wildlife Conservation for Development IP, support was provided to educate national project staff about connectivity conservation and to create ecological and climate corridors to enable the movement of target species among PAs (e.g. in the Colombian Amazon, Ecuador, and Indonesia). Planning and management for corridors typically require a species-by-species approach; for example, a corridor that enables the movement of African elephants will not necessarily meet the needs of wild dogs.

   An additional, more holistic management framework, based on conservation mosaics (large landscapes and seascapes that integrate multiple levels of protection, jurisdiction and human use), focuses more on socio-ecological systems and overall landscape permeability – the degree to which landscapes, including a range of natural, semi-natural, and developed land cover types – will sustain ecological processes and are conducive to the movement of many different organisms in the context of both climate and land-use change.[59] Landscape permeability is especially important for the large-scale ecological changes happening in the Anthropocene. These changes involve thousands of species and many ecosystems shifting in various directions over long periods, driven by climate and land-use change and by intensifying resource use and extraction.[60]

57 The United Nations Convention on Conservation of Migratory Species of Wild Animals (CMS) defines ecological connectivity as "the unimpeded movement of species and the flow of natural processes that sustain life on Earth". (CMS 2020)

58 Ward et al. 2020.

59 Lawler et al. 2025.

60 Ibid.

Permeable landscapes accommodate these complex ecological changes and require that biodiversity conservation focuses more holistically on the management of entire landscapes and seascapes.

Brazil pioneered an ambitious conservation mosaic approach in 27 large landscapes, beginning in 2000 (see Box 3). More recently, in GEF-8 and also through the GBFF, South African National Parks is implementing Mega Living Landscapes, another conservation mosaic approach (see Box 4). In the marine realm, the governments of Colombia, Costa Rica, Ecuador, and Panama have created the Eastern Tropical Pacific Marine Corridor (ETP), covering more than 500,000 km^2. Although referred to as a corridor, the ETP takes a large-scale, conservation mosaic approach to maintaining ecological and climate connectivity for an array of marine PAs of varying sizes and levels of protection, including long-distance migratory routes for many species (e.g. leatherback turtles, whale sharks, hammerhead sharks). With support from a large coalition of donors,[61] the ETP takes a holistic, multinational approach to strengthening the regional governance of marine ecosystems, ensuring regional connectivity, improving climate-resilient management, and coordinating investments in the blue economy with conservation efforts.

b. **Identify and support the protection of climate change refugia** for biodiversity – areas that are relatively buffered from contemporary climate change, enabling terrestrial and marine species and ecosystems to persist.[62] See Boxes 2 and 5 for illustrative examples.

Projects aiming to expand networks of PAs and OCEMs would benefit from prioritizing the protection of KBAs – especially in tropical forests and coral reefs – that serve as refugia from novel ecosystems and climates. Ensuring that both existing and emerging terrestrial and marine refugia are fully incorporated into PA networks is one of the strongest pathways to securing long-term ecosystem function, preventing local extinctions, and enhancing the future resilience of biodiversity and ecosystem services.

In some cases, it may make sense to prioritize the protection of climate refugia (see Box 2) over other conservation efforts, such as restoration. For example, the persistence of coral reefs globally is in question and protection of those that can persist is important.

The GEF needs to closely monitor and integrate the emerging science on climate refugia, as refugia hold significant potential to provide multiple co-benefits, including improved productivity and livelihoods and potentially buffering human communities from extreme events.

61 Donors include Bezos Earth Fund, Blue Nature Alliance, Development Bank of Latin America, Enduring Earth, German Federal Ministry for Economic Cooperation and Development (BMZ) through the KfW German Development Bank, GEF, Gordon & Betty Moore Foundation, Green Climate Fund, Islas Secas Foundation, Minderoo Foundation, Pew Bertarelli Ocean Legacy, Re:wild, Shark Conservation Fund, UK government, US Department of State, and Wyss Foundation.

62 Morelli et al. 2020.

Box 3: Brazil's Conservation Mosaic Framework

In 2000, Brazil enacted the National System of Protected Areas Management legislation, including 27 mosaics, which requires coordinated and integrated management of multiple jurisdictions across a landscape, ranging from national parks to Indigenous and Traditional Territories, with the aim of increasing large-scale biodiversity conservation, enhancing sociocultural diversity among stakeholders, and advancing sustainable local development.[63] A national council, comprising Indigenous Peoples, community members, and federal, state, and municipal administrators is responsible for the oversight of the entire system.

Brazil's mosaic approach is notable for several reasons:

i. The overall management approach acknowledges the mosaics as complex, ***socio-ecological systems*** requiring the integration of ecological, social, economic, and cultural considerations.

ii. The ***collaborative governance*** approach (i.e. the coordination of planning and actions across multiple landowners, regulatory and governing entities, and other actors such as conservation non-governmental organizations, and other stakeholders) contributes to inclusive and equitable governance.

iii. The approach ***manages for connectivity*** within and beyond PAs by maintaining ***landscape permeability*** to enable shifts in species ranges and ecosystems in many directions and over both short and long distances.

The Amazon Region Protected Areas Program (ARPA),[64] which began in 2002, has provided essential funding to support Brazil's federal and state PAs, both strict PAs and sustainable use PAs. Beginning in 2015, ARPA for Life provided additional support, and critically, created a long-term source of Government funding for Brazil's PAs. In 2025, at UNFCCC COP30, Brazil announced the creation of ARPA Communidades (Communities). ARPA Communidades applies the Project Finance for Permanence approach to create a 120 million US dollars, 15-year sinking fund to support the creation of new sustainable use PAs and, importantly, to support 130,000 local and traditional peoples to diversify and improve their livelihoods and community resilience.

63 https://ipe.org.br/en/protected-areas-mosaic-project.

64 https://www.thegef.org/sites/default/files/publications/Arpa_GEF%202018_22.01.18-v2.pdf.

Box 4: South African Mega Living Landscapes for people and nature

Two coordinated GEF projects, led by South African National Parks, with the World Wildlife Fund as the GEF agency, are applying the conservation mosaic model in South Africa, creating three large-scale interconnected landscapes that integrate national parks and other PAs with productive lands in surrounding communities, in the Addo, Barberton, and Grasslands Mega Living Landscapes (MLLs). The two projects are strategically linked. One, supported by the GEF Trust Fund (GEF-8), is implementing the three MLLs; the other, supported by the GBFF, is developing a durable funding source for the MLLs, using the Project Finance for Permanence model.

In total, the three MLLs will conserve 20,000 km^2, comprising conservation and production landscapes with different legal statuses and management regimes, including strict PAs, OECMs, Indigenous Peoples and local community lands, and private land used for sustainable production (e.g., regenerative agriculture). MLLs take an integrated approach to addressing biodiversity loss, climate change, and land degradation and maintaining landscape permeability, while also improving livelihoods and human well-being. As with the Brazil mosaics, the MLLs emphasize institutional partnerships and inclusive governance.

The MLLs play a key role in SANParks Vision 2040, a transformative strategy to guide the future of conservation in South Africa, moving away from a fortress conservation[65] approach to one that envisions a future where nature, heritage, and conservation are integral to every South African's life and where human well-being is deeply intertwined with environmental health and sustainability. The MLLs are innovative, not only in their implementation of the conservation mosaics approach to maintain landscape permeability and in their durable finance approach, but in their innovative leveraging of GEF resources – strategically combining support from both the GEF Trust Fund and the GBFF – which provides a model for other countries.

65 Fortress conservation, often a colonial legacy, involves designating strict PAs to conserve biodiversity and can displace or exclude Indigenous Peoples and local communities.


oto: iStock

Box 5: Maintaining landscape permeability for climate refugia in Madagascar

Madagascar is globally recognized for its extraordinary species diversity and its endemism, with approximately 90% of its plant species[66] and nearly 100% of its mammal species[67] found nowhere else on Earth. Scientific research suggests that forest taxa moving along riparian forests[68] in a retreat–dispersion pattern during historic periods of rapid climate change[69] and climatic unpredictability[70], has led to Madagascar's high levels of endemism. This has created optimism that the mechanisms that enabled past climate change adaptation may operate now and in the future. If connectivity is maintained or restored this will support the ability of species to track the speed of climate change and increase opportunities for dispersal and colonization in response to shifting climate.[71] More specifically, species in Madagascar may adapt to current and future climate change if riverine forest corridors and effective management of isolated forest patches, including restoration, provide sufficient landscape permeability for species movement.

Madagascar has lost more than 80% of its natural areas and, since 2000, 25% of its tree cover.[72] The largest remaining block of high-integrity forest in Madagascar is in eastern Madagascar, in Makira Natural Park, and Masoala and Marojejy National Parks. Makira's forests provide critical connectivity among PAs in the region. Maintaining high-integrity forests in Makira, Masoala, and Marojejy is essential to the resilience of Madagascar's eastern rainforests to current and future climate change.[73] Estimates of the value of ecosystem services of this forest landscape in 2008 ranged from 150 US dollars/hectare/year for cropland to over 5,000 US dollars/year for tropical forests, with the total value of ecosystem services provided by the landscape estimated at approximately 3 billion US dollars per year.[74]

Given the widespread poverty in Madagascar, it is imperative that conservation strategies to address climate change, deforestation, and degradation, and to ensure durable GEBs, explicitly address co-benefits and improving human well-being. Continued commitment by the Government of Madagascar and the international community, including the GEF, to the conservation of biodiversity and ecosystem services during periods of political instability is also essential.

c. **Explicitly consider the implications of climate change for maintaining and restoring ecosystem services.** GEF projects involving ecological restoration can focus on continuing the delivery of ecosystem services (supporting, provisioning, regulating, and cultural services), explicitly considering the implications of climate change for restoration objectives, rather attempting to re-establish historic species assemblages or reference states, which may not be possible.

In GEF-9, the GEF will support several restoration initiatives. This includes support for landscape restoration in the Critical Forest Biomes IP, focusing on activities that contribute to maintaining or rehabilitating ecosystems. This IP will also target forest restoration to foster biodiversity conservation and connectivity among primary forests. The Blue and Green Islands IP will also invest in restoration of terrestrial and marine ecosystems through a source-to-sea approach. The aim of these efforts

66 Goodman 2023.
67 Antonelli et al. 2022.
68 Ganzhorn & Sorg 1996.
69 Wilmé et al. 2006.
70 Dewar & Richard 2007.
71 Hannah et al. 2008.
72 Suzzi-Simmons 2023.
73 Morelli et al. 2020.
74 Masozera 2008.

is to maintain or improve ecosystem functions and improve livelihoods while generating GEBs. Additional efforts in GEF-9 will include investments through the Food Systems IP, which aims to restore degraded lands and ecosystems to enhance land productivity and ecosystem services. The Drylands and Drought Management IP will also prioritize restoring ecosystems and degraded land as part of a strategy to build drought resilience.

Currently, there is increased attention on coral reef restoration.[75] However, approximately 40% of coral reef restoration projects currently fail because of unrealistic objectives, inadequate maintenance, and persistent anthropogenic stressors.[76] Further, coral restoration, even for only a handful of target species, is extremely expensive,[77] making widespread restoration challenging.[78] Additionally, restoration sites tend to be close to human settlements, making them vulnerable to local pollution.[79] As such, prioritizing the identification and conservation of coral reef climate refugia as mentioned above, may also be advisable.

Restoration projects would benefit from explicitly considering interactions between biodiversity and climate mitigation and adaptation measures, including ensuring coherence between land-use and sea-use objectives and planning in national biodiversity and climate strategies. Restoration that integrates the priorities of the three Rio Conventions, rather than implementing projects for each convention separately, can not only be effective, but also more cost-efficient. For example, a restoration project in Rwanda found that integrating the three Rio Conventions saved approximately 45 million US dollars per year compared with siloed implementation.[80]

75 Eighty-four percent of the world's coral reef area, and mass coral bleaching has been documented in at least 83 countries and territories, according to the National Environmental Satellite, Data and Information Services (NOAA).

76 Mulà et al. 2025.

77 Hughes et al. 2023; Hein et al. 2021; Bayraktarov et al. 2019; Bayraktarov et al. 2016.

78 Mùla et al. 2025.

79 Ibid.

80 Mirzabaev, A. et al. 2023.

4. CONCLUSION

This information note emphasizes that in the context of global change, characterized by increasing rates of change across all components of the Earth system, conservation policy and management need to embrace and respond to change. In GEF-9, projects designed to deliver durable GEBs will need to focus on managing change, using approaches that maintain and enhance ecological connectivity, protect refugia, and sustain ecosystem function and services in ways that are resilient and are responsive to local cultural and political contexts.

In addition to climate risk screening of all GEF projects and considering plausible futures in project design, the GEF needs to closely monitor and integrate emerging science on connectivity, ecosystem novelty, climate refugia, conservation mosaics, and changing delivery of ecosystem services. These areas and approaches can help identify key pathways to maintaining biodiversity, as well as promoting co-benefits such as improved productivity and livelihoods and strengthened buffering from extreme events. When biodiversity, climate, land degradation, and international waters goals are pursued together, the results can be stronger, more cost-effective, and more durable.


Photo: iStock

ANNEX. A SELECTION OF RESOURCES AVAILABLE TO SUPPORT BIODIVERSITY CONSERVATION IN THE ANTHROPOCENE

A variety of resources is available to support biodiversity conservation planning, management and restoration in the Anthropocene. This annex does not provide an exhaustive inventory of resources but, rather, highlights a few relevant tools and approaches.

i. 30×30 Integrated Conservation Priority Assessment Tool was developed by scientists at the Wildlife Conservation Society, with funding from the Gordon & Betty Moore Foundation, to guide the integrated implementation of GBF Targets 1 and 3 and climate solutions for terrestrial areas. It provides spatially explicit information on areas with high biodiversity value, high ecosystem integrity, large amounts of carbon in vegetation biomass and soils, and high potential to support adaptation for nature and people, thus enabling prioritization for conservation action. The tool enables interactive visualization of 10 key data layers for all terrestrial land globally, including visualization of climate stability using CMIP6 data from CHELSA version 2.1.[81]

ii. BioShifts Database is a global geodatabase of climate-induced species range shifts over land and sea that enables users to explore the impacts of species range shifts on nature and society.

iii. STAP has developed a simple future narratives brief and primer to support the design of projects that are resilient and have durable outcomes, highlighting the importance of several drivers of change that are relevant in the Anthropocene (e.g. population, conflict, climate change, and migration).

iv. Spatial Planning for Protected Areas in Response to Climate Change (SPARC) was a GEF-supported project, led by Conservation International and the University of California, Santa Barbara, aimed at increasing the effectiveness of PA networks in the face of climate change.[82] SPARC and its successor, SPARCLE, have developed an app and an associated SPARC methods manual for exploring the modelled responses to climate change of more than 17,000 species of amphibians, birds, mammals, and reptiles. SPARCLE applies these models to make land-use trade-offs of conservation visible and to facilitate long-term planning in the context of climate change. The raw data used for the SPARC prioritization also are available.

81 Karger et al. 2017.

82 Hannah et al. 2020.

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