TRENDS
BIODIVERSITY

Biodiversity Corridors: Strengthening ecological connectivity to adapt ecosystems to climate change

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The American Conservation Movement in the 19th century gave birth to the first great national parks with the idea that the best way to protect nature was to isolate certain spaces from human activity. Faced with the alarming observation of biodiversity decline in recent years, conservation is undergoing a paradigm shift, both in its definition and in the governance of protected areas where the role of indigenous peoples and local communities in managing them is being increasingly defended. This new vision of conservation underscores the significance of the degree of connectivity between ecosystems, for which ecological corridors are an important instrument.

DATA OVERVIEW

The convergence of climate, biodiversity and desertification issues, which intensified following the Covid-19 pandemic, highlights the challenge of reconnecting environments

The zoonotic nature of the SARS-CoV-2 virus, originating from the collapse of natural boundaries between animal and human species, has highlighted the interconnections between different ecosystems as well as between climate, biodiversity, and soil management. Among the emergent infectious diseases, 75%[1] appear to be zoonoses, which circulate from animals to humans or vice versa, and which have been on the rise since the 1980s. The reasons for this rise are the trade in and consumption of wild animals, the degradation of ecosystems constituting their natural habitat, and global warming, which shrinks their geographical range.[2] This is what was first advanced by a community of experts and researchers with the "One Health"[3] concept before it was put on the political agenda during the Covid-19 crisis. This concept promotes a future course of action that would take human as well as animal and environmental health into account.[4] Politically, it is reflected in the reconciliation between the conventions signed at the Earth Summit in Rio in 1992 and it encourages the linking of their objectives. This vision takes climate action out of a "carbon-centric" view, highlighting the co-benefits to be promoted along with the Sustainable Development Goals (SDGs).[5,6]

The practical application of this holistic vision can be found in the increasing integration of biodiversity into the funding mechanisms for climate action. Funding that is favourable to biodiversity doubled between 2012 and 2020, from 52 billion dollars[7] annually to approximately $130bn,[8] of which 80 to 85% comes from public funds. This evolution parallels the

growing attention paid by actors to "nature-based solutions". Having been dominated by renewable energy projects for a long time, the voluntary carbon market is now switching towards projects dedicated to forests and land use (45% of credits issued in 2021).[9] Labels certifying the contribution of carbon credits to the preservation or restoration of biodiversity are also appearing in major certifying bodies. Thus, the Climate, Community & Biodiversity Standards of the American Verra standard (VCS) listed in July 2022 contains 49 validated and 71 verified projects, and more than 291,690,000 credits issued with the label (accounting for about 30% of all credits issued by Verra).[a] These credits, which also certify co-benefits, trade at a higher value on the market.[10]

This trend towards the incorporation of co-benefits for biodiversity can be seen within the REDD+ mechanism,[b] the initial purpose of which was to preserve forests for their role as natural carbon sinks. REDD+ in fact aims to assign a financial value to carbon stored in forests to encourage their preservation. In recent years, REDD+ deeds have focused increasingly on forests located in protected areas to reinforce their positive externalities to the benefit of ecologically strategic areas. The preservation of forests has a direct positive impact on biodiversity because forests are home to a very large part of Earth's biodiversity – 75% of birds, 80% of amphibians and 68% of mammals.[11] The volume of REDD+ credits aimed at avoiding unplanned deforestation increased by 166% between 2020 and 2021, and by 972% in the case of planned deforestation. Other incentivising mechanisms promote actions aimed at preserving or restoring biodiversity, such as Payments for Ecosystem Services (PES).

At the political level, inclusion of biodiversity in the agenda was notably marked by the COP10 of the Convention on Biological Diversity (CBD), when the signatory states meeting in Nagoya adopted a strategic plan for biodiversity for the period 2011-2020, including the twenty Aichi targets. Objective C.11 set the ambition for the surface area of protected land to reach 17% in 2020, and the new goals for the 2020-2030 decade are expected to be set this at 30%. However, according to the ProtConn[c] index, the surface area of protected areas was only 14.7% in 2020. Only a third[12] of the countries have managed to achieve the Aichi C.11 target as of 2017, mostly in Europe and Micronesia. But although the surface of protected areas doubled between 1990 and 2018,[13] biodiversity continues to decline: the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) still listed a million species headed for extinction in 2019.[14] The conservation of protected areas is itself threatened not only by the impacts of climate change, but also by invasive species, increased tourist numbers, poaching, wildfires, and water pollution. In a report assessing the conservation of natural World Heritage sites published in November 2020, the International Union for Conservation of Nature (IUCN) believes that since 2017, the situation has further deteriorated.[15]

Although they are essential for the preservation of ecosystems and species, protected areas and national parks are also the cause of loss of genetic diversity. Protected areas and parks are in fact delimited,[16] which hinders the migration of species and therefore the congregation of different groups of the same species. However, biodiversity, as defined by IPBES,[d] is assessed in part according to the rate of genetic variation within a given habitat. Protected areas in the form of islets are not suitable for large-ranging species, called "umbrella species". For instance, it hinders the natural migration of jaguars,[17] and the limited size of the areas does not allow species like elephants[18] to meet all their needs.

The United Nations stressed in 2020 that SDG 15 on the conservation of biodiversity cannot be achieved with the current state of protected areas[19] and with the increase in fragmentation of natural habitats. This observation comes along with a paradigm shift regarding the conservation of biodiversity which highlights the concept of an "ecological conservation network". An ecological network includes protected areas, intact natural areas, and Other Effective area-based Conservation Measures (OECM), which constitute its "core conservation units". The connections between these critical habitats are achieved with "ecological corridors", and the whole of these parts constitutes an ecological network. The network is "*established, restored as necessary, and maintained to conserve biological diversity in fragmented environments*".[20] Connectivity between these areas could be damaged by climatic events or anthropogenic activities such as land use and farming, construction of infrastructure such as buildings, roads, railways, dams, electricity networks, etc. Connectivity thus materialises through the ability of ecosystems to be physically connected and not separated by physical barriers. This connectivity can be through land, sea, air, or a mix of these.[e]

Today, according to the ProtConn index, only half of protected areas are connected. Some countries already show a relatively high degree of connectivity between their protected areas: Brazil, Venezuela, Peru, Morocco, Guinea, Benin, the Republic of Congo, Namibia, Botswana, Zimbabwe, Tanzania, Armenia, Tajikistan, Sri Lanka and Bhutan. Conversely, India, Indonesia, Malaysia, Papua New Guinea, China, Australia and the United States, which account for approximately 60%[21] of biodiversity loss, all exhibit a low degree of connectivity between their protected areas **(FIG. 1)**. Other countries are also particularly under threat, such as Kenya, Nigeria and Pakistan,[22] where

a See the Verra Registry

b The REDD+ (Reducing Emissions from Deforestation and Forest Degradation) mechanisms were developed by the parties to the United Nations Framework Convention on Climate Change (UNFCCC), i.e., one of the three conventions signed in Rio in 1992.

c The ProtConn index, which was set up in 2016 by the Digital Observatory for Protected Areas within the framework of the joint research centre of the European Commission, aims to assess the degree of connection within a given region or country, particularly between protected areas.

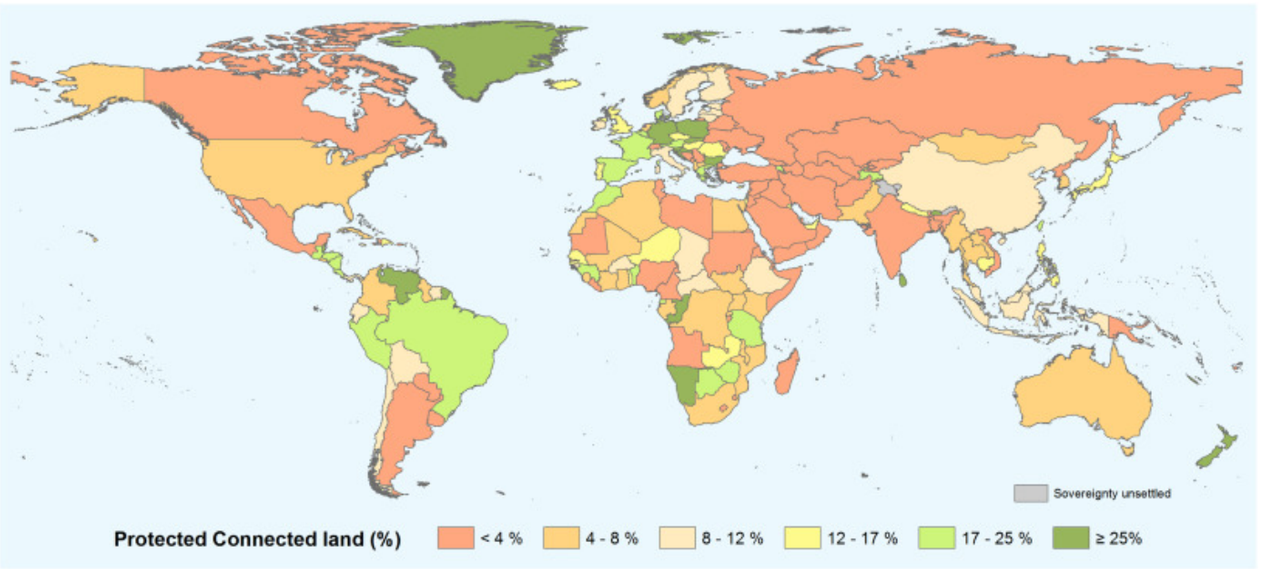
d See the IPBES glossary

e The term "connectivity" can also be used in an urban area to describe projects that aim to improve the coexistence, in an urban environment, of human activities with the presence of biodiversity – the development of green infrastructure, for example.

FIGURE 1

PORTION OF CONNECTED PROTECTED LAND BY COUNTRY

Source: Biological conservation, March 2018



farming, which is very important for the economy, is based on fragile ecosystems. At the global level, more than 30%[23] of ecosystems in one-fifth of countries are at risk of collapse, according to the index of the Swiss Re Institute Biodiversity and Ecosystem Services.

The connectivity between critical habitats in conservation networks are provided through what are known as "corridors" – "*a clearly defined geographic area that is governed and managed over the long term with the aim of maintaining or restoring an effective ecological connectivity*".[24] Corridor boundaries can nevertheless evolve over time in relation to the transformations of the territory, climatic events, or the construction of new infrastructures. They can take various forms: hedges, agricultural paths, streams, etc. but are not always continuous and can constitute "stepping stones".[f] Corridors are often large projects which require several years studying species and land mapping, as well as management requiring close collaboration between actors. They are generally set up around strategic areas – such as forests or bodies of water – which often come into conflict with the human activities that also exploit these areas. In Sri Lanka, the elephant corridor, for example, was blocked in May 2021 by local farmers who needed space for their farming activities.[25] But the goals of biodiversity conservation rely on the protection of 50 key eco-regions in just 20 countries, which in many cases overlap with areas populated by indigenous communities.[26]

THE OBSERVATORY'S LENS

Biodiversity corridor projects highlight the contribution of collaborative approaches and are used for adapting to climate change

The 25 corridor examples studied in the IUCN[g] report show that certain projects implemented in the 2000s and yielding results today are those which managed to be designated as "corridors" or which have been established in areas officially recognised as protected areas. This official and legal recognition helps establish "conservation frameworks" which facilitate the set up and management of these corridors. In particular, the integration of corridor projects into public planning seems to be a *sine qua non* for the success of such projects, so that the space of the corridors is known, and does not come into conflict with other land use projects carried out by a neighbouring country or by other actors within the country.

As strategic spaces for resources, both for animal species and human populations, transnational borders are often the subject of corridor projects. These cross-border projects have been made possible thanks to inter-state agreements via a

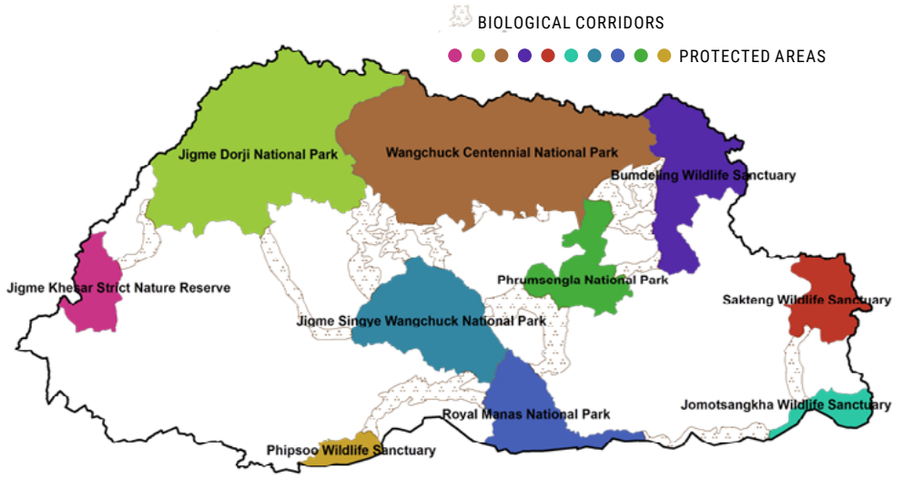
f "Stepping stones" is a term used specifically to define strategic areas on long migration routes (for species such as marine mammals, sea turtles, and birds) whose aim is to ensure access to food as well as to provide tranquillity and security, and thus make the migration feasible.

g Unless otherwise stated, the examples referred to in this Trend are cited in the report *Guidelines for conserving connectivity through ecological networks and corridors* (see References)

FIGURE 2

PROTECTED AREAS AND BIOLOGICAL CORRIDORS OF BHUTAN

Source: Bhutan Biodiversity, n.d.



shared integration of the corridors into the various national plans. This is, for example, the case of the Kavango-Zambezi cross-border conservation zone (ZCT) at the intersection of the borders of five countries (Angola, Botswana, Namibia, Zambia, and Zimbabwe) and the Albertine Rift region concerning five countries (Burundi, the DRC, Rwanda, Uganda, and Tanzania). In the first case, a "cross-border ecological network" was recognised: the five countries produced a development plan (which was integrated into the national plans) to clearly describe the connection that each of the plans has with the others. In the second case, the MacArthur Foundation provided the funds for a "collaborative planning" approach with the aim of drawing up a conservation framework plan as well as detailed conservation plans. Once the plans were issued, Memorandums of Understanding (MOUs) were established.

Integrating corridor projects into national and local planning can act as a lever to limit land conflicts over the use of the territory. The protected areas are often surrounded by land in use, particularly for farming or by private parties, and the management of corridors in these territories often involves dealing with land use conflicts. This is the case of the restoration project of the Kilombero Valley Ramsar site in Tanzania in 2000, which used to be a natural refuge for migration of species during the dry season until the transformation of the landscape in the 1990s (increased agriculture, grazing, livestock and deforestation, due to the increase in population of the region). Recovery projects for certain corridors in the area have been relatively successful: although they are indeed used by many species, the corridors have had to face major land disputes with local owners, farmers, etc. This is why an integrated management plan was launched in 2016 by the Ministry of Natural Resources and Tourism, the main aims of which were improved coordination (which was practically non-existent) of the use of land in the territory between villagers, private owners, local communities, and farmers, in favour of the harmonisation of land protection and control of practices.

Home to 5% of the world's biodiversity, Costa Rica has been one of the pioneer countries in biodiversity conservation policies since the 1990s. Its policies were mainly based on one programme for protected areas, one for biodiversity corridors, and municipal land management plans. The integration of the project at the level of national policies, and following that, into the municipal plans, has allowed Costa Rica to showcase one of the most advanced policies on conservation in the world. Thus, *"Biological Corridors are not State conservation areas, but rather a separate conservation strategy implemented by the National System of Conservation Areas within the framework of the national biological corridors programme"*.[27] Since the 1990s, 40 corridors representing 38% of the territory have been set up[28] and land management plans make it possible to control activities in the territory. However, a recent assessment has shown that the corridors did not always fulfil the goal of reducing fragmentation of the territory in certain locations. In the view of the authors,[29] the results of the corridor projects in terms of connectivity could be improved if they were prioritised in government policies.

Ranked among the poorest countries on earth in GDP per capita, Bhutan has succeeded in setting up biodiversity corridors since 1999 at the initiative of the Queen Mother, thereby ensuring the conservation of 51% of its territory. Bhutan's corridors extend over 2,966.53 km², one of the largest corridor areas recorded in the Protected Planet database. The royal authorities and the government have based their country's biodiversity conservation strategy on the corridors, being pioneers in this vision of conservation. Bhutan is also one of the only countries in the world that enacted laws specifically aimed at ecological corridors via constitutional decrees.[30] Since 2008, Bhutan's constitution has set a target of protecting and conserving 60% of its territory.

The management of ecological corridors is more effective when in collaboration with local populations

Once established, corridors require detailed observation and careful management. The absence of data regarding the management and protection (via ex-post evaluations) of protected areas and corridors is one of the key points of the 2020 report from Protected Planet[31] for the 2020-2030 decade. In addition to ensuring compliance with the corridor objectives, these observations serve to limit the risks. Corridors can faster propagation of certain diseases, of invasive species, or even the spread of forest fires. This is why collaboration with local populations and their complete inclusion in corridor projects will help the monitoring and long-term existence of the corridors.

The projects with good results so far are those that involved a very detailed collaboration between all actors at a national and local level. This collaboration is usually enabled and facilitated by third-party actors, such as international foundations or NGOs that play an intermediary role between national and local governments and local populations. These intermediaries first raise awareness of the project and establish contact between the various communities before ensuring the redistribution of the benefits to the local populations. They also play a supporting role in financing, as in the case of lawyers responsible for defending the perspective of local communities regarding the corridor projects. This is what the African Wildlife Foundation (AWF) did to launch the corridor projects for the Kilimanjaro landscape, by funding a Maasai lawyer on behalf of the community, which was then able to discuss the lease before it was signed without the presence of AWF (the community thereby feeling free to provide additional input).[32]

Since it affects the human activities that surround the protected areas, achieving corridor project objectives is partly the result of successful co-management between landowners, biodiversity conservation NGOs, and communal ground managers. This coordination is difficult to establish in view of the many actors with their different interests, and the legitimacy conflicts that may arise.[33] The projects highlight the need for the decentralisation of the management of areas and corridors; the following can be read in the IUCN report on the establishment of corridors within the Ramsar site of the Kilombero valley in Tanzania: "*A long-term vision anchored in the conservation agencies could in principle underpin a long-term adaptive management process, but a shared vision, financial resources and institutional capacities are not yet available for the implementation of the plan.*"[34] It also emphasises the benefits of a transition from centralised management to "mosaic" management of smaller areas which are located on farmland, for example. This horizontal collaboration involving areas that constitute the corridors is also highlighted by the national corridor programme managed by the national government along with the local communities. For example, they are responsible for creating specific regulations on the use of land that concerns them.

The association of local communities also resurrects historical knowledge on the territory and movements of species. In the case of the Kavango-Zambezi ZCTs, it was the local communities who pointed out that a certain area in the project "*used to be a haven for animals and mobile species such as elephant and buffalo*".[35] In the case of the Albertine rift in Central Africa, the local communities helped in the study of the territory for the implementation of the corridor project to the benefit of the conservation of their ancestral territory.

Namibia, Nepal and Bhutan constitute three strategic eco-regions for biodiversity which have achieved a level of conservation and protection covering at least 50% of their territory.[36] To ensure the connectivity between the protected areas, the first two have established communal management of the connecting territories and Bhutan implemented biodiversity corridors **(FIG. 2)**.

Other types of financing are also common for biodiversity conservation. For example, the financing of corridor projects in northern and southern Kenya is based on three major instruments: REDD+ action programmes, payments for ecosystem services, and "community conservancies".[37] More than 60 conservation communities have been established in northern and southern Kenya, in territorial continuity with northern Tanzania. They promote community governance of the territory, numerous social benefits, and ensure reliable contact with donors and investors. Nevertheless, the Oakland Institute's *Stealth Game* report,[38] published in November 2021, presents a critical view of these community conservancies. Based on testimonials and complaints from recent years, the report states that the establishment of conservation communities would be carried out at the cost of an overwhelming presence of the *Northern Rangeland Trust* on the lands of pastoralists, who no longer have any power over the management of their land and who do not benefit from tourist activity revenues in these territories.

Conservation and corridor projects also generate new sources of income for local populations, based on the value placed on the biodiversity that these populations help to protect and conserve. In particular, the financial benefits generated by conservation tourism facilitate funding the management of protected areas and the corridors connecting them. The establishment of the corridors itself can also generate new jobs, such as scouts, in the case of the Kilimanjaro project, or local patrollers, in the ZCTs of Kavango-Zambezi, for example. In this region, new activities have emerged, such as "conservation agriculture".[h] Finally, projects may depend to a greater or lesser extent on donors.

h According to the definition given by the FAO, conservation agriculture "*is a farming system that prevents the loss of arable land while regenerating degraded land. It promotes maintaining a permanent soil cover, minimal disturbance of the soil, and diversification of vegetable species. [...] It opens up increased possibilities for the integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes*".

However, as the Peoples Forests Partnership pointed out at COP26 in November 2021, indigenous peoples receive only 1% of international climate finance assistance, while helping to conserve almost one fifth of the carbon sinks in tropical and semi-tropical forests.[39] In central Africa, 85% of protected areas is managed by a public authority, 14% is managed through shared governance, and 1% through community or private management.[40] At the global level, however, the management by indigenous peoples proves effective and yields results that are better than or equivalent to those of public managers in protected areas.[41] The very management of protected areas is therefore increasingly turning towards the promotion of community management. The creation of protected areas and national parks has often been done to the detriment of local communities who have lost the management and use of these lands. This is the purpose of the "LandBack" movement, born in the United States in October 2020 by leaders of indigenous peoples,[42] which aims to recall the transgenerational knowledge of their people about the history of their land and the skills for its management. The defence of this added value endorsed by the movement is based in particular on a criticism of the conservation of nature, such as it had been advocated by the first American naturalists in the 19th century, and which led to transformation of their lands into national parks – contrary to the traditional usage of the territory,[43] and without taking into account the millennia of land management by indigenous peoples.

Corridors allow species to adapt to climate change

By facilitating their migration, the corridors allow wild species to adapt to seasonal changes and ecological disturbances aggravated by climatic changes, such as wildfires or water scarcity. The delimitation of protected areas can in fact impede the ability of species to avoid these disturbances, because the biological richness of an ecosystem also promotes its stability and its ability to adapt to climate change. In fact, "*at local scales, it is likely that ecosystems with greater biodiversity are more productive and more stable through time*"[44] In this sense, the connectivity networks boost the resilience[i] of biodiversity in the face of climate change and enable the migration of species in order that they may better adapt to climate change. Numerous measures have been identified in academic research to address this problem: "*increasing the number and size of protected areas and OECMs; managing habitats to increase their resilience; establishing or widening connectivity areas; locating reserves in areas of high heterogeneity*".[45, 46, 47] To boost this resilience, researchers focus on reinforcing the conservation of existing natural habitats rather than increasing the size of protected areas.[48] To allow adaptation to temperature variations, it is necessary to ensure connectivity between different geographical areas: from a high-altitude area to a low-lying area, from a continental area to a coastal area, etc. This is the case of the Albertine Rift in Central Africa, where the aim was to strengthen existing corridors and take into account the different reliefs and altitudes. One of the drawbacks of re-establishing connectivity between two areas would be the appearance of invasive species in areas they did not previously occupy, but this phenomenon is observed mostly in marine networks.[49] The main advantage of corridors is that they benefit most species, unlike stepping stones.

The expression "climate-wise connectivity" (the use of which was popularised in 2018) describes the role of connected ecological networks in adapting to climate change. This approach goes hand in hand with the paradigm shift associated with nature conservation, taking into account the consequences of climate change. The establishment of corridors to support adaptation to climate change therefore requires, initially, a careful study of the territories and the consequences of climate change for them in order to identify the locations where these corridors will be most effective.

Several studies on the implementation of this concept have focused on the mountainous coasts of northern California. This area provides an example of climate-adapted connectivity that has yielded many results. The first assessment of climate change in California dates back to 2006, and the fourth gave rise to a report dealing with connectivity reinforcement strategies.[50] This report presented thirteen approaches to implementing climate-adapted connectivity based on the species involved, the geography of the landscape, etc. The field study identified areas that were particularly resilient to climate change, "*areas where today's climate will persist into the future and places with low climate velocity*".[51] The report also points out the difficulty of converting official planning into concrete projects and notes the low number of climate-adapted corridors put in place so far, thereby emphasising the importance of the results of the corridors already established in California. The establishment of biodiversity corridors depends on the objectives of the project: corridors that have climate change adaptation as their main objective will therefore not require the exact same corridor modelling methodology. This does not prevent it from contributing to other objectives, such as the migration of species, genetic diversity, etc.

i Ecological resilience is the ability of a system to withstand disturbances – fires, climate change, human disturbances – and to reorganise and regenerate itself in a manner that always preserves the same functions and characteristics.

KEY TAKEAWAYS

Having come to the forefront in recent years, the connections between climate and biodiversity issues make it possible to understand the cascading effects of global warming on the decline of biodiversity, and *vice versa*. Nevertheless, the conservation of biodiversity, as it has been conceived up to now, has not really made it possible to limit its decline, nor to adapt it to climate changes. The recent assessment of the corridors established at the end of the 1990s underscores the fact that they could be a tool for the strengthening of biodiversity connectivity and for the adaptation of species, if they are conceived as such. The latest results have shown that having once passed the field study and seed funding stages, corridor projects were often threatened by a complex management among the miscellaneous stakeholders and by being disregarded in national planning.

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