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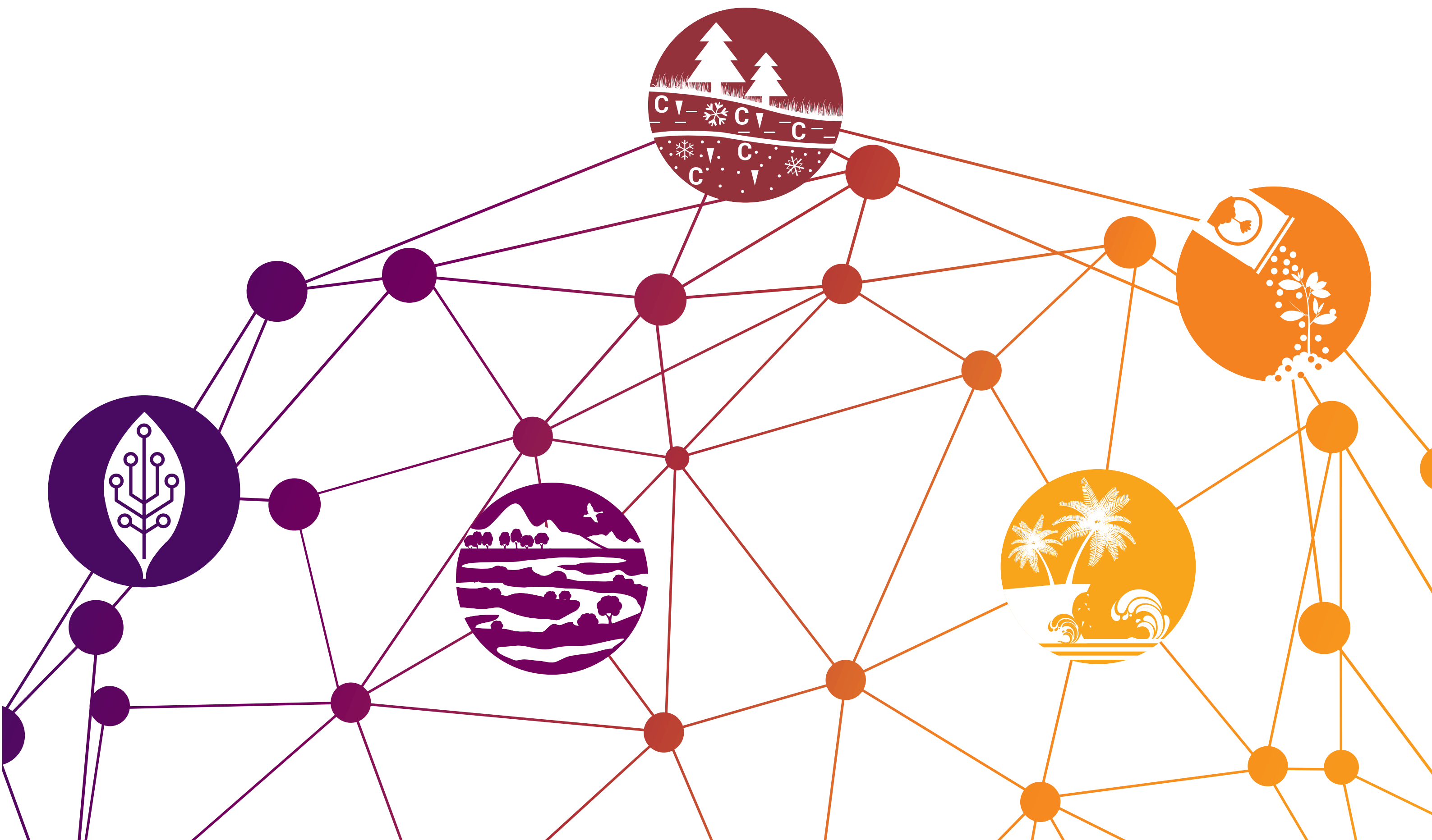
FRONTIERS 2018/19

Emerging Issues of Environmental Concern



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Emerging Issues of Environmental Concern

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Foreword

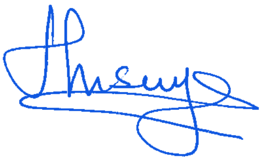
In the first decade of the 20th century, two German chemists – Fritz Haber and Carl Bosch – developed a way to produce synthetic nitrogen cheaply and on a large scale. Their invention spurred the mass production of nitrogen-based fertilizers, and thus transformed farming around the globe. It also marked the beginning of our long-term interference with the Earth's nitrogen balance. Every year, an estimated US$200 billion worth of reactive nitrogen is now lost into the environment, where it degrades our soils, pollutes our air and triggers the spread of "dead zones" and toxic algal blooms in our waterways.

It's no wonder that many scientists are arguing that "the Anthropocene" should become the official name of the current geological era. In just a few decades, humankind has caused global temperatures to rise 170 times faster than the natural rate. We have also deliberately modified more than 75 per cent of the planet's land surface, and permanently altered the flow of more than 93 per cent of the world's rivers. We are not only causing drastic changes to the biosphere, we are also now capable of rewriting – and even creating from scratch – the very building blocks of life.

Every year a network of scientists, experts and institutions across the world work with UN Environment to identify and analyze emerging issues that will have profound effects on our society, economy and environment. Some of these issues are linked to new technologies that have astonishing applications and uncertain risks, while others are perennial issues, such as the fragmentation of wild landscapes and the thawing of long-frozen soil. Another issue, nitrogen pollution, represents an unintended consequence of decades of human activity in the biosphere. While the final issue analyzed here, maladaptation to climate change, highlights our failure to adequately and appropriately adjust to the shifting world around us.

There is some good news to report. As you can read in the pages that follow, a holistic approach to the global challenge of nitrogen management is beginning to emerge. In China, India and the European Union, we are seeing promising new efforts to reduce losses and improve the efficiency of nitrogen fertilizers. Ultimately, the recovery and recycling of nitrogen, as well as other valuable nutrients and materials, can help us to farm cleanly and sustainably, a hallmark of a truly circular economy.

The issues examined in Frontiers should serve as a reminder that, whenever we interfere with nature – whether at the global scale or the molecular level – we risk creating long-lasting impacts on our planetary home. But by acting with foresight and by working together, we can stay ahead of these issues and craft solutions that will serve us all, for generations to come.



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Ecological Connectivity: A bridge to preserving biodiversity

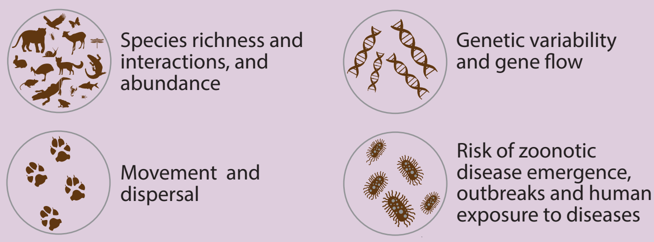
Reconnecting fragmented ecosystems

Nature was once vast and boundless, but in an industrialized, 21st century world, this is no longer the case. Across the globe, landscapes and seascapes are becoming more fragmented. Wildlife has less freedom to roam and free-flowing rivers are increasingly rare. Along tropical coastlines, previously seamless gradients of mangroves, seagrass meadows and coral reefs are now more fractured, undermining essential productivity and ecosystem resilience to natural and anthropogenic disturbances.[1] A consequence of the segmentation of natural landscapes is that mammals and other species are moving less than half the distance they once did.[2] This limited ability to migrate, disperse, mate, feed and thrive means that wild animals are cornered into situations where the threat of extinction looms larger.

Fragmentation is typically a symptom of landscape transformation and destruction. The division of habitat into fragments has three specific effects: a reduction of overall habitat area and quality, increased isolation of small habitat patches, and increased disturbance associated with artificial boundaries of habitat fragments, or 'edge effects'.[3-6] Isolated and smaller patches of habitat mean fewer species and smaller populations in each patch, with restricted interactions among habitat patches. Increased fragment edges expose populations within the patch to external disturbances along the boundaries. Eventually, when a patch becomes too small and isolated, viable populations and species richness can no longer be sustained.[5] Fragmentation ultimately leads to a downward spiral of cascading ecological dysfunctions, from the unravelling of food webs, to the loss of critical ecological processes such as mineral and nutrient flows, to direct extinction of species.[3,5,7-9]

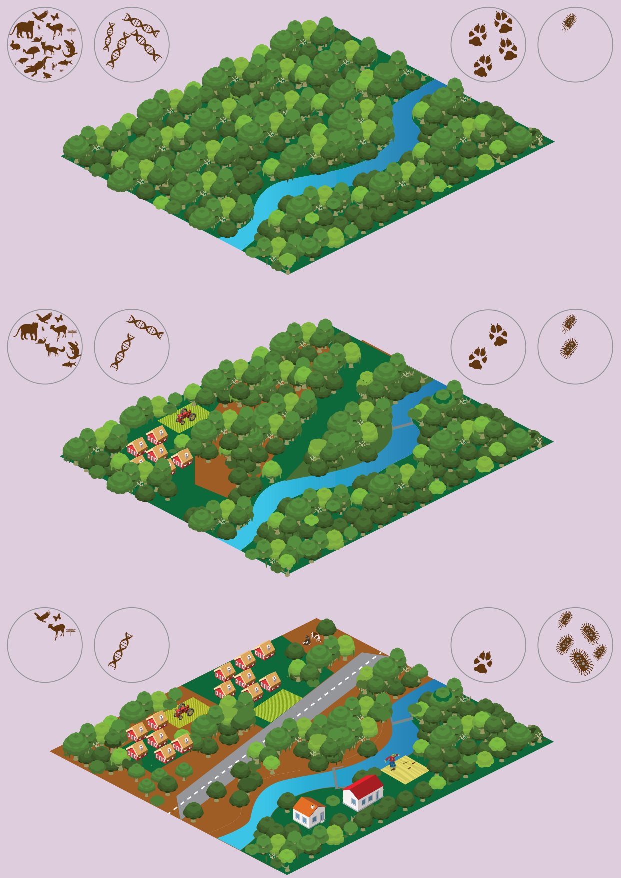
Maintaining or restoring connectivity between fragmented habitats or landscape patches has been identified as the key to counteracting many of the negative impacts of fragmentation.[10] Connectivity can be defined as the degree to which landscapes and seascapes allow species to move freely and ecological processes to function unimpeded. Scientific evidence built on island biogeography research and species meta-populations studies overwhelmingly demonstrates that connected habitats are more effective in preserving species and ecological functions.[11,12] Connected ecological communities and habitat patches sustain vital ecological processes such as pollination, productivity, decomposition, and biochemical and nutrient cycling. Ecological connectivity can also help species adapt to future environmental conditions and buffer changes by bolstering ecological resilience to disruptive threats such as climate change.[13]

Despite the obvious advantages, the world's nations currently lack a consistent approach to implementing connectivity conservation. What are the best measures to assess success for connectivity conservation? How do governments and conservationists create corridors, design ecological networks, or determine the effectiveness of connectivity conservation efforts? The conservation of intact landscapes and seascapes through the designation of more or large-scale protected areas is feasible, but requires making difficult political, social and economic choices.[14,15] Connectivity as a conservation target requires shared goal setting among stakeholders to ensure multidimensional consideration and implementable coordinated action. Public and private sectors must work together for effective outcomes because stopping biodiversity loss and reducing the impact on ecosystems is a shared responsibility of both sectors, from the community level to a global scale. In many instances, connectivity efforts can incorporate local socioeconomic concerns within a larger conservation framework.



Habitat fragmentation

About 40% of terrestrial ecosystems have been converted into agricultural landscapes.[16] Land and river transformation for human use leads to habitat fragmentation. Smaller and more isolated fragments of habitat surrounded by human activities are less likely to maintain the function and survival of animal and plant inhabitants. Habitat fragmentation negatively affects abundance, distribution, movement, species richness and interactions, reproduction and genetic diversity.[5] It impairs the ability of species to adapt to new climatic conditions.[17]



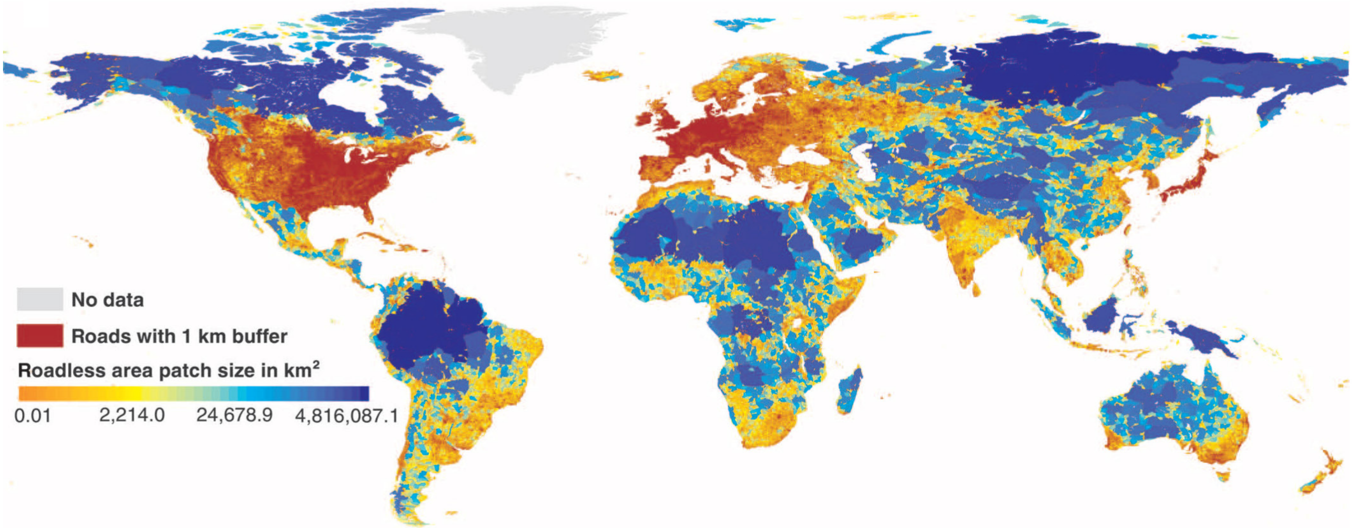
The forces of fragmentation

Societies are transforming the Earth's biosphere and reshaping its ecology in unprecedented ways. The latest research indicates that more than 75 per cent of the planet's land surface has been modified by humanity.[18-21] Human population pressures, growing urbanization, agricultural expansion, pollution, and infrastructure development all work in synergy as fragmentation forces. Some land-use projections estimate that by 2050, roughly one billion hectares of tropical land could be cleared specifically for agricultural needs.[22] The marine environment is even less immune to these trends: new research shows that of the world's oceans, only around 13 per cent is still classified as marine wilderness, much less than many conservationists had expected.[23]

Linear infrastructure is often the tip of the spear of modern development. Roads, rails, pipelines, fences, and canals are being built at record rates, especially in remote, previously undeveloped regions of the tropics. Ninety per cent of all new road construction is expected to occur in developing nations.[24] In India, where nearly 60 per cent of the world's tiger population is found, critical tiger corridors are threatened by 4,300 kilometres of newly planned national and state roads.[25] Globally, over 25 million kilometres of new roads are anticipated by 2050 – a 60 per cent increase in the total length of existing roads in 2010.[26]

Free-flowing rivers, the ecological lifeblood of landscapes and estuaries, are challenged by the fragmentation resulting from the size and scale of the ongoing construction of dams. Large dams divide 59 per cent of global rivers into sections, disrupting the natural flow of 93 per cent of the global river volume, with nearly 28 per cent considered to be under heavy or severe flow regulation.[27] In the Amazon basin alone, there are currently over 400 dam projects being developed, constructed, or planned.[28] Together, dam construction, road building and deforestation work to undermine the ecological integrity of continental river basins, which also has real consequences for other human economic and recreational activities. For example, freshwater connectivity contributes approximately US$200 million per year to the Amazon basin fishing economy that provides employment for roughly 200,000 anglers.[29]

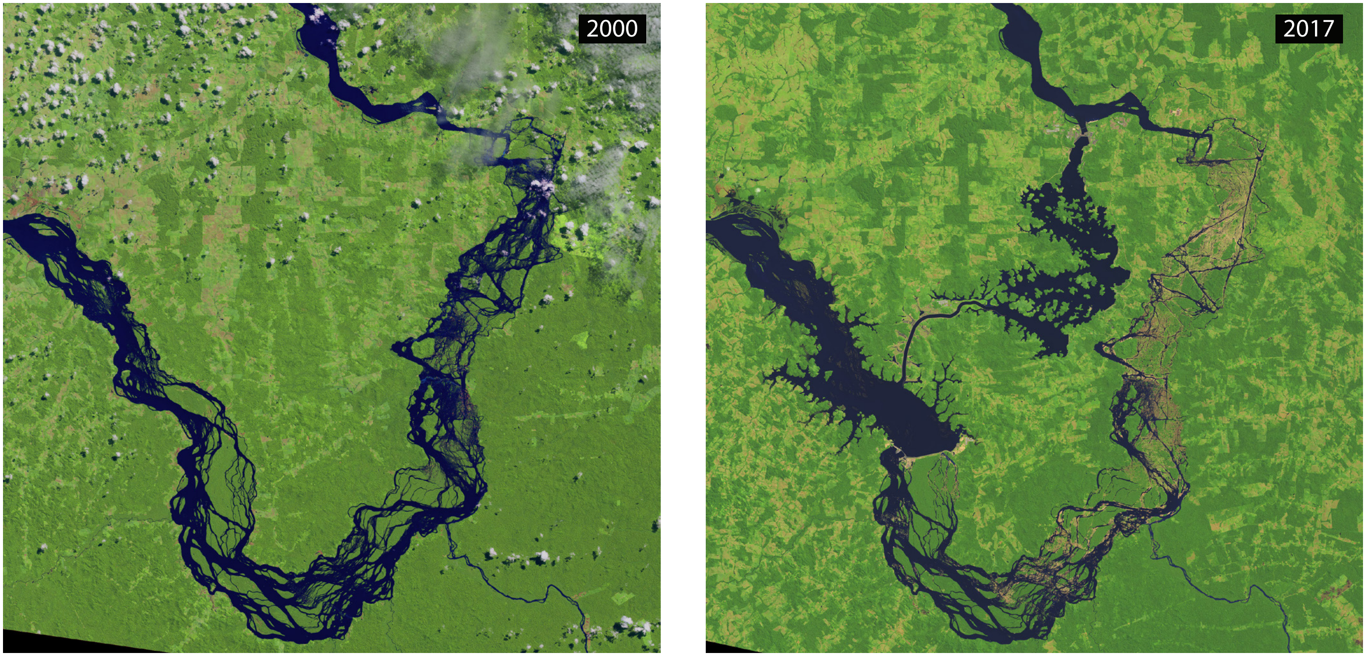
Landscape fragmentation by roads



An analysis of a dataset of 36 million km of roads across the world shows that roads have fragmented the earth landscape into more than 600,000 patches. More than half of these patches are within 1 km range of any road (in red). Moving towards the blue shade are land patches further away from all roads and less influenced by road effects.

Source: Ibisch et al. (2016)[30]

Xingu River in northern Brazil in 2000 and 2017



The construction of the Belo Monte hydroelectric dam project in 2011 has completely reshaped the Xingu River. More than 80% of the river flow has been diverted, causing large areas to dry up and directly affecting indigenous communities and wildlife living in the area.

Photo credit: Joshua Stevens / NASA Earth Observatory

Rivers, landscapes and coastlines are inextricably linked. Connectivity is also a recognition that nature operates as an integrated sum of its parts. Connectivity between aquatic and terrestrial systems is vital to ecological integrity and too often, these elements are managed as separate units. In temperate ecosystems, for example, research has shown that the footprint of gravel-bed river floodplains extends well beyond riparian zones. This influence on sub-surface terrestrial ecology projects beyond visible river channels and their deltas, reaching further into the marine realm. Free-flowing river systems work to connect aquatic, avian, and terrestrial communities – from microbes to grizzly bears – influencing the biogeochemistry of landscapes and seascapes along the way.[31]

Video: Seed dispersal and forest fragmentation

Video link: https://www.youtube.com/watch?v=0m6AjWZ2p8I
Photo credit: Jess Kraft / Shutterstock

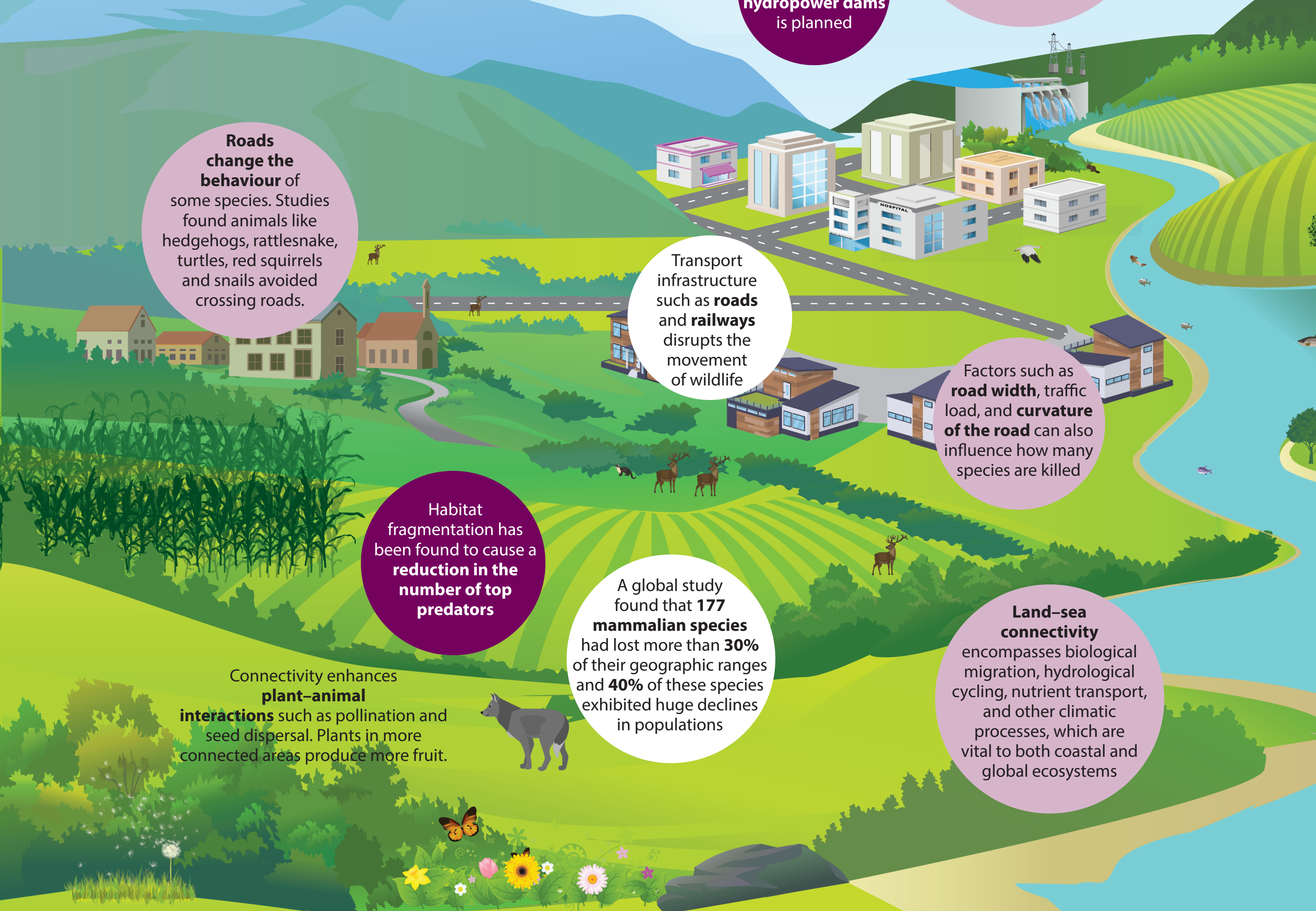
Landscape fragmentation and connectivity

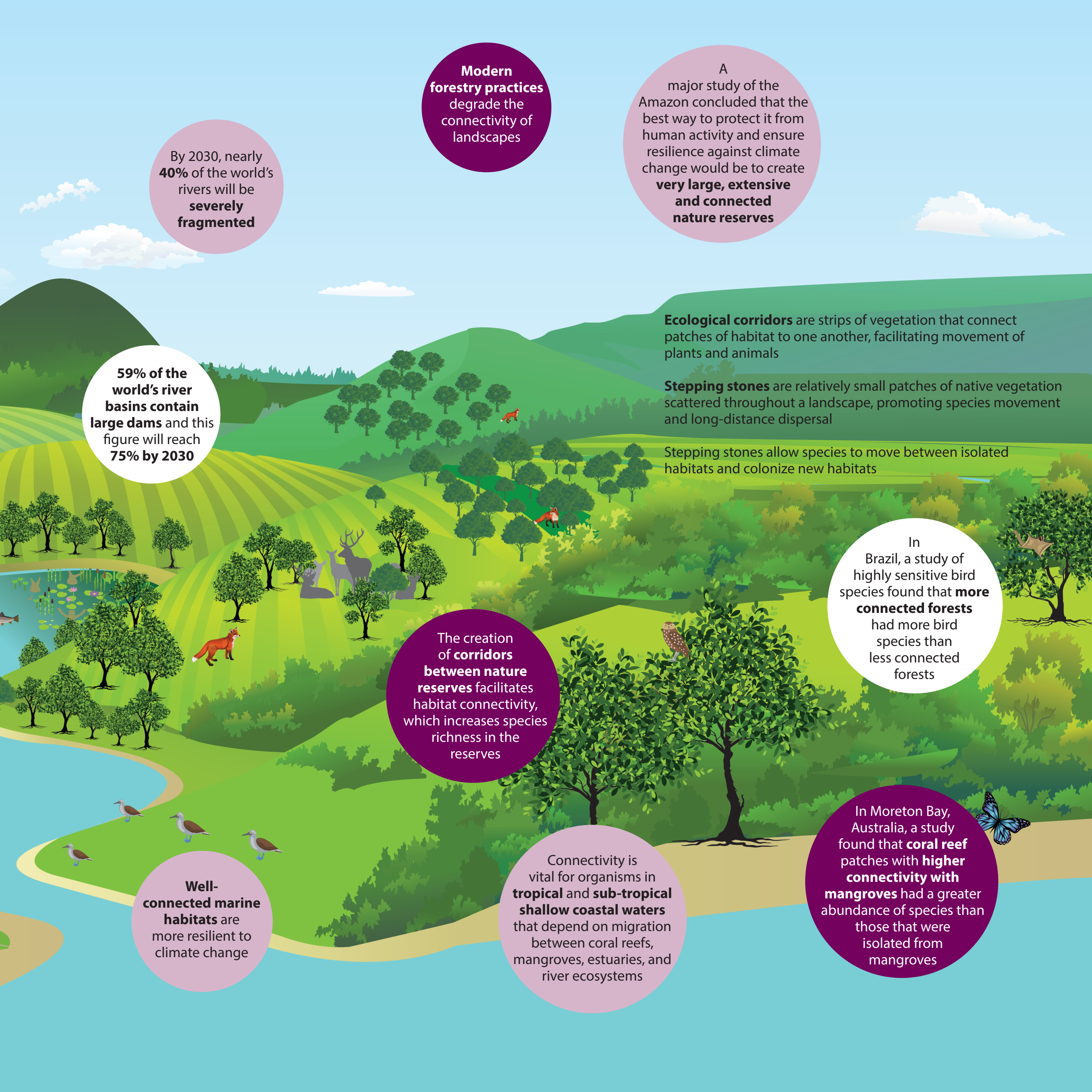
Landscape fragmentation is the subdivision of large, continuous habitats into smaller, more isolated pieces or patches.

Landscape connectivity is a measure of the extent to which a particular landscape allows the free movement of animals and other ecological flows.

As the climate warms, maintaining connectivity between areas of different temperatures could allow organisms to move along **temperature gradients**, permitting species to adapt

Well-connected spaces allow species to migrate to new habitats, especially when they need to **adapt to climate change**





By 2030, nearly **40%** of the world's rivers will be **severely fragmented**
Modern forestry practices degrade the connectivity of landscapes
A major study of the Amazon concluded that the best way to protect it from human activity and ensure resilience against climate change would be to create **very large, extensive and connected nature reserves**
59% of the world's river basins contain large dams and this figure will reach **75% by 2030**
Ecological corridors are strips of vegetation that connect patches of habitat to one another, facilitating movement of plants and animals
Stepping stones are relatively small patches of native vegetation scattered throughout a landscape, promoting species movement and long-distance dispersal
Stepping stones allow species to move between isolated habitats and colonize new habitats
In Brazil, a study of highly sensitive bird species found that **more connected forests** had more bird species than less connected forests
The creation of **corridors between nature reserves** facilitates habitat connectivity, which increases species richness in the reserves
Well-connected marine habitats are more resilient to climate change
Connectivity is vital for organisms in **tropical** and **sub-tropical shallow coastal waters** that depend on migration between coral reefs, mangroves, estuaries, and river ecosystems
In Moreton Bay, Australia, a study found that **coral reef** patches with **higher connectivity with mangroves** had a greater abundance of species than those that were isolated from mangroves

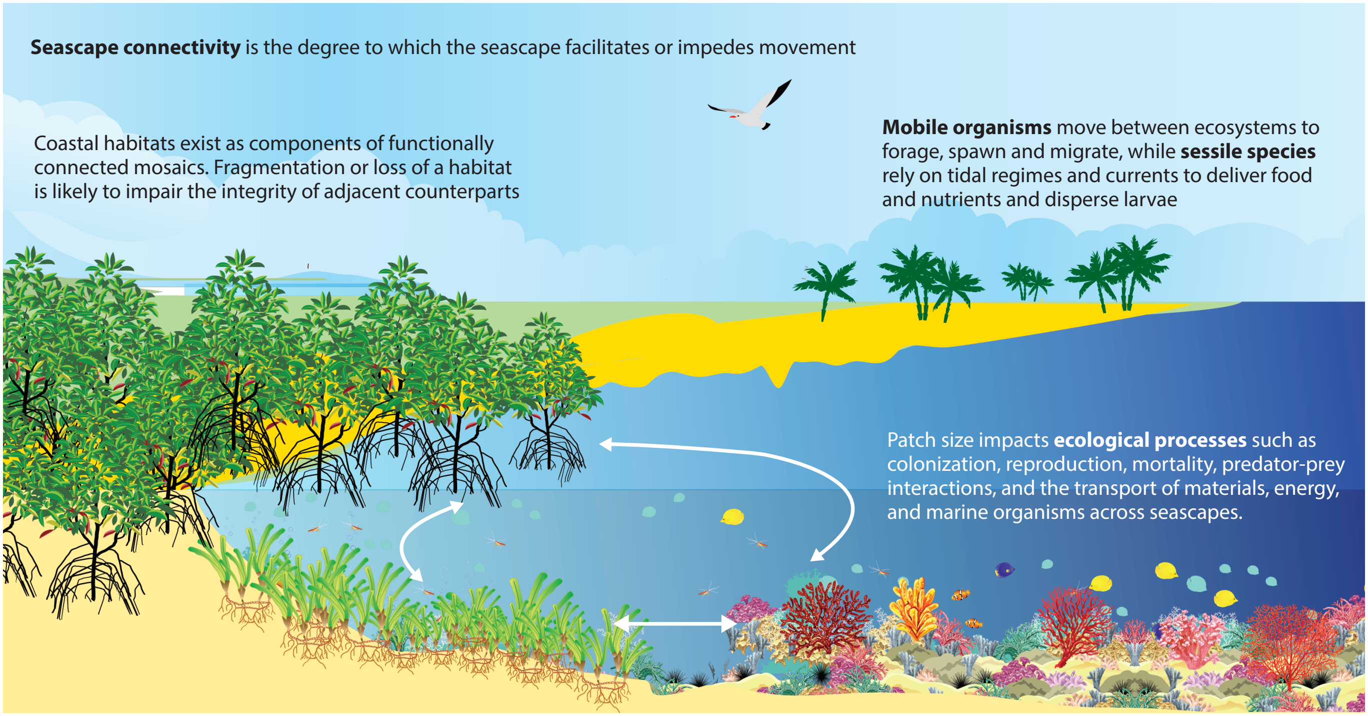
Promoting connectivity solutions

Connectivity conservation is the antidote to fragmentation and in a time when the threats to nature are at scales that stretch both human and financial-response capacity, progressive initiatives are being implemented by some countries. In Brazil, connectivity conservation underlies the country's ambitious efforts to restore viable habitat connections within the heavily fragmented Atlantic rainforest, the Mata Atlantica. Some endangered species have been the focus of restoration projects aiming to connect isolated populations, for example, the golden lion tamarin. Targeted restoration has been shown to reduce species extinction rates in once-fragmented forest blocks.[32] Connectivity is now the stated objective of various Brazilian biodiversity policies. The Brazilian Forest Act and Brazil's Native Vegetation Protection Law specifically highlight connectivity as a critical landscape restoration and habitat conservation strategy. [33,34] The government of El Salvador has recently proposed that the period 2021–2030 be declared the "United Nations Decade of Ecosystem Restoration" with the aim to restore and enhance landscape connectivity and ecological functions.

In Africa, the Government of Tanzania recently passed a new Wildlife Conservation Act that emphasizes the need for greater wildlife corridor conservation among its protected areas. In Kenya, where most wildlife is found outside of protected areas and county-level planning has just begun, the Kenya Wildlife Service has systematically catalogued the nation's key wildlife corridors and dispersal areas, and has crafted a national wildlife corridor policy.[35]

Within the global marine realm, connectivity functions in a three-dimensional way as the water column adds an additional variable to movement ecology. The sea itself is a connecting medium. Thus, marine connectivity is manifested in multiple ways across marine-coastal connections, surface-seafloor interactions, and as part of ocean current dynamics.[36]

Seascape connectivity



It is almost impossible for Marine Protected Areas, the cornerstone of ocean conservation, to function as ecological isolates in this highly connected environment. As such, the sea is conducive in creating ecological networks that connect critical habitats across space and time.

Furthermore, the complex life histories of many marine species have evolved with the movement dynamics of this fluid world. Seagrasses and mangrove swamps are well-known nursery habitats for the young of many marine species, which then often need to travel to coral reefs, seamounts, or other waters to mature. Seascape connectivity is emphasized as a key guiding principle in marine conservation and spatial planning, as well as restoration efforts; however, in practice it is rarely incorporated into the design of marine reserve networks.[36-39] This is largely due to the scarcity of quantitative data on multiple aspects of connectivity in the design phase, for example, the dispersal and movement patterns of key species at different life stages, ecological connectivity within and outside reserves – as well as between habitat types, and genetic connectivity among populations.[10,38-40] Nevertheless, studies of interactions between connectivity and the performance of marine reserves in the Caribbean, Florida Keys, Solomon Islands, Moreton Bay and the Great Barrier Reef in Australia demonstrate the ecological importance of greater connectivity. Positive effects on fish abundance, species richness and composition, recruitment and various ecological processes were observed in these protected areas.[10,41-44]

Efforts have been made by the international community to promote connectivity solutions. In 2016, the International Union for Conservation of Nature (IUCN) established the Connectivity Conservation Specialist Group (CCSG) to catalyze and energize the growing practice of connectivity conservation. Comprising around 900 members from 80 nations, the CCSG is focused on building capacity for the practice of consistent connectivity conservation worldwide by developing networks and providing guidance through a combination of scientific, engineering and policy expertise.

Video: What's marine connectivity?

Video link: https://www.youtube.com/watch?v=MowPR5GYqKM *© Ifremer*
Photo credit: Damsea / Shutterstock

Video: Behind the scenes of the red crab migration—Christmas Island 2012

Video link: https://www.youtube.com/watch?v=n9yl51LQ0sI *© Parks Australia*
Photo credit: David Stanley

Setting targets for future connectivity

The Aichi Biodiversity Targets adopted as part of the implementation of the Strategic Plan for Biodiversity 2011–2020 by the Convention on Biological Diversity (CBD) encompass the issues of landscape and seascape connectivity. The Aichi Biodiversity Target 11 states that at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas are to be protected worldwide in a well-connected system of protected areas. Yet many scientists believe that current biodiversity conservation deserves a more ambitious goal.[45,46] The conservation science community argues that, on average, 50 per cent of all lands and seas need to be managed in order to sustain the ecological processes that maintain nature and critical planetary health thresholds, including ecosystem services that support human livelihoods.[4,14,15] For many areas of global ecological significance, a bolder target is scientifically warranted and politically supported. For instance, the Amazon basin requires greater protection to sustain this vast watershed's regional and global hydrological and climate functions. If the Amazon loses more than 20 per cent of its forests, landscape models predict a threshold flip in conditions that would support tropical savannah rather than forest, resulting in impacts on global climate patterns.[47] In implementing the Aichi Biodiversity Targets, the Brazilian government established its own goal to protect 30 per cent of the Amazon while ensuring that other biomes within its territory would individually meet the 17 per cent target.[48] The next ten-year CBD strategic plan covering 2021–2030 will be negotiated in October 2020 in China. There is enthusiasm among the conservation community that the goals of Aichi Biodiversity Target 11 could be framed more ambitiously and in line with the aspiration of "50% for Nature" by the year 2050.

While much effort has focused on meeting the protection percentages for lands, freshwater and seas, it is also recognized that more could be done on the modifying element of a well-connected system of protected areas, and other effective area-based conservation measures. The science unequivocally demonstrates that connected protected areas are more effective protected areas.[49,50] Connecting fragmented landscapes and seascapes through ecological networks can effectively enhance the functionality of nature and boost more ambitious approaches to conservation.

Wildlife corridors are a widely accepted connectivity strategy for protecting species migrations. Corridors are often designed for and focused on a particular species, such as pronghorn antelope in North America, tigers in Asia, and spotted jaguar in South America. Corridors come in an array of shapes and sizes depending on the species of concern and the constraints of the landscape, ranging from discrete linear trails to series of "stepping stone" habitat patches that facilitate migration of birds or sea turtles.

Linkage zones are larger landscape or seascape areas that serve a wide array of species and ecological processes in order to maintain connectivity. These zones comprise large swathes of land or sea that facilitate dispersal between protected areas, which is critical in places like East Africa where an overwhelming majority of wildlife is found outside of protected areas. Linkage zones also facilitate the movement of animals, biomass, and energy between habitat patches, or among different ecosystems within protected areas.

Permeability areas are the largest-scale concept used by conservationists to protect connectivity values in human-dominated regions outside of protected areas. These areas support the seasonal needs or spatial extent of species movement and/or ecological processes, such as vernal pools or specific freshwater hydrologic flows.

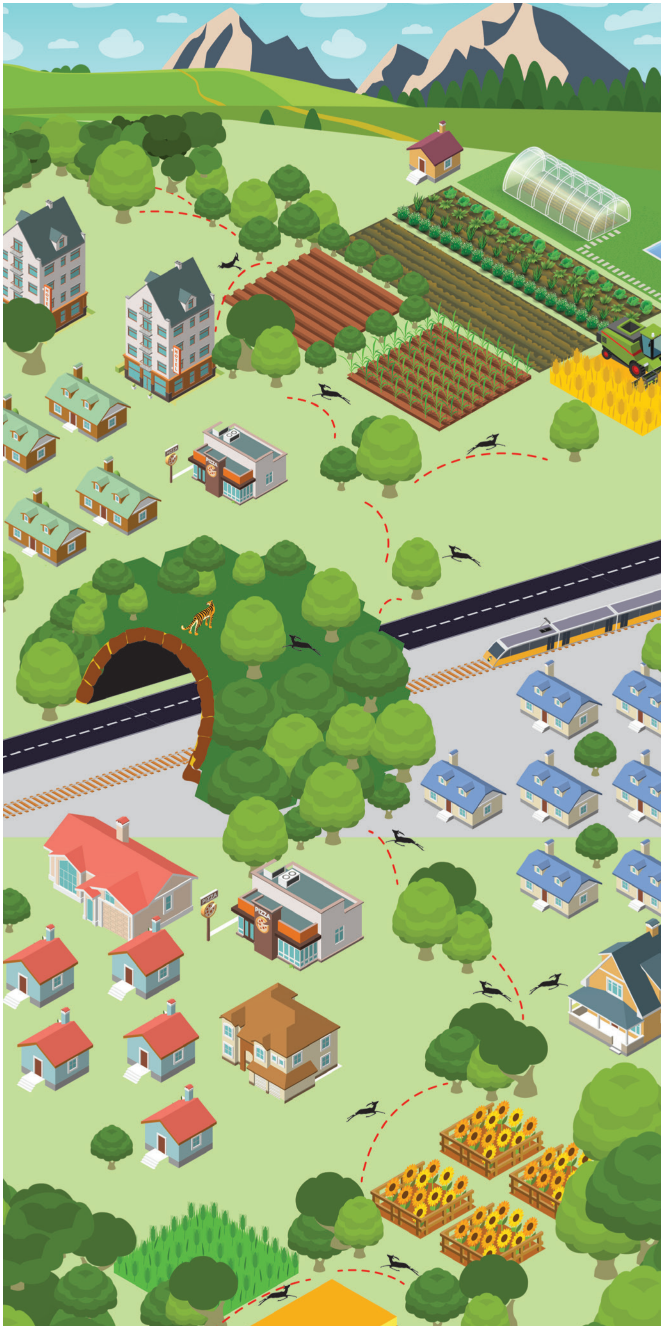
Climate corridors are proposed by scientists as a means to conserve species movements along temperature gradients; these same corridors often serve as 'climate refugia'.[51] Some connectivity conservation efforts explicitly include climate resilience in their objectives, such as the Great Eastern Ranges Initiative in Australia.[52]

Presently 14.7 per cent of land around the world is covered by protected areas and less than half of this coverage is connected.[50] As this statistic suggests, there is much opportunity for improving connectivity between protected areas globally. If the world seeks large-scale conservation action rapidly, connecting protected areas through ecological networks offers hope.

The application of connectivity conservation is still relatively nascent within wider conservation practice, and there is much to learn to perfect best practices.[53,54] As an emergent practice, ecological connectivity conservation faces its greatest implementation challenges outside of protected areas. Limiting impacts from fragmenting forces such as linear infrastructure development is obviously a critical need. Educating policymakers, government agencies, and local community stakeholders about the importance of ecological connectivity is equally crucial. While some nations could introduce regulatory measures to conserve connectivity, the vast majority of ecological connectivity efforts will rely on incentive-based participatory conservation approaches.[55] The adaptation of existing environmental policies could facilitate the wider adoption of connectivity conservation by including connectivity targets within both environmental impact assessments, and various conservation finance and tax incentive programmes.

Protected areas alone cannot save biodiversity or conserve the interconnected ecological functions that sustain life on this planet. Connectivity is the embodiment of ecology, which is the science of interdependence. This is imperative as interconnected lands, freshwater and seas are the lifeblood of intact nature. Thus, connected networks represent the best opportunity to maintain and restore ecological and evolutionary processes, avoid extinctions, and protect terrestrial, freshwater, and marine ecosystems vital to humanity and all life. Connectivity could ensure that ecosystems around the world will be more resilient and adaptable to global change, and will have the ability to sustain the ecological integrity that meets the needs of present and future generations. Until the forces of fragmentation are overcome, connectivity conservation by design creates a safety network for biodiversity conservation – and ultimately, humanity.

Stepping stones and crossing



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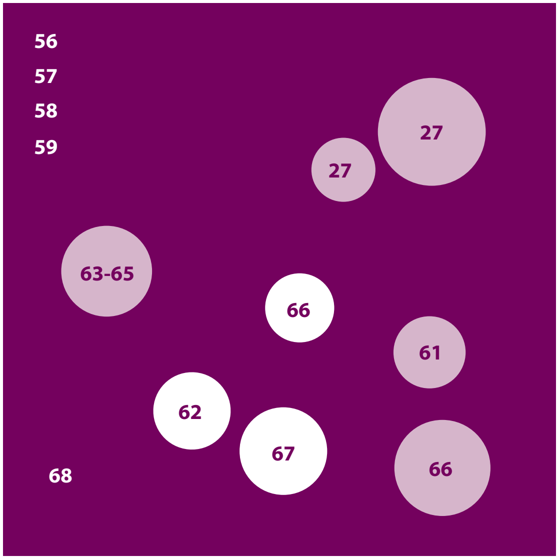
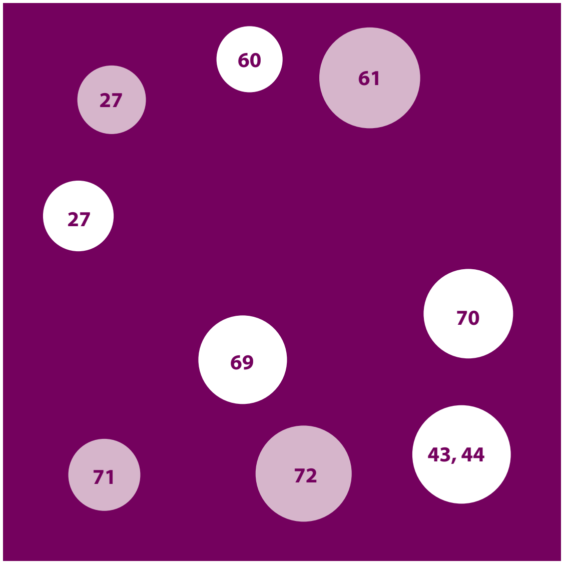
Graphic references





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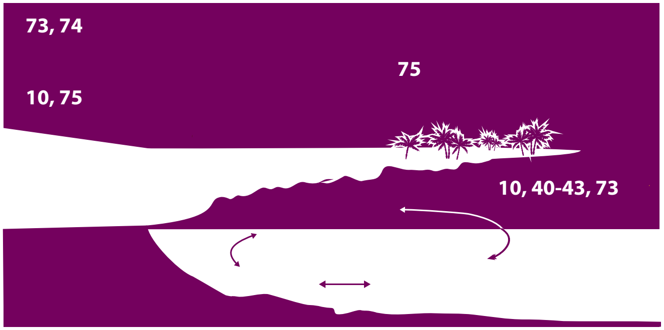

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