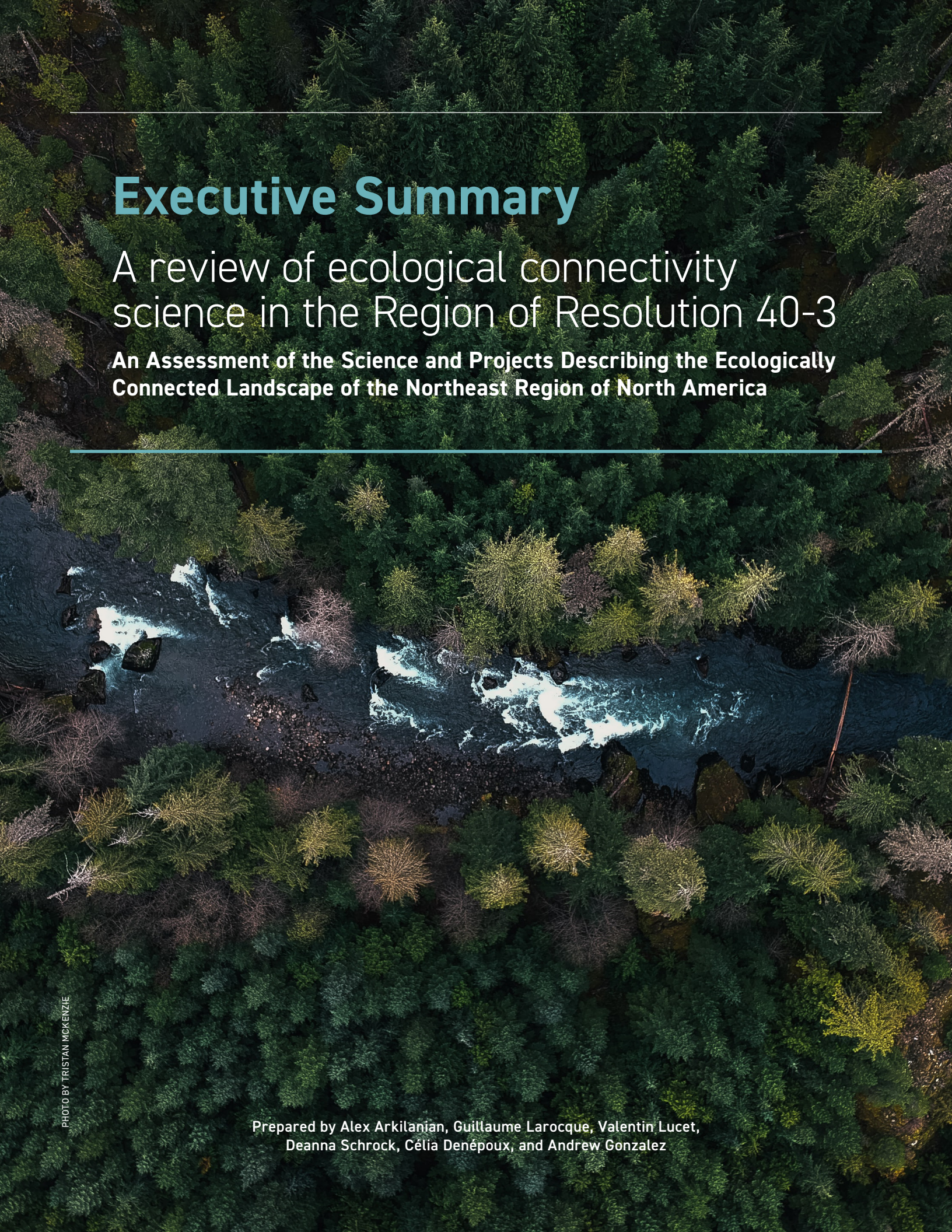
Executive Summary

A review of ecological connectivity science in the Region of Resolution 40-3

An Assessment of the Science and Projects Describing the Ecologically Connected Landscape of the Northeast Region of North America



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At the 40th Conference of New England Governors and Eastern Canadian Premiers (NEG-ECP) held on August 28 and 29, 2016, the Governors and Premiers adopted Resolution 40-3, titled "Resolution on ecological connectivity, adaptation to climate change, and biodiversity conservation." The resolution highlights the "importance of ecological connectivity for the adaptability and resilience of our region's ecosystems, biodiversity, and human communities in the face of climate change," "the need to work across landscapes and borders to advance efforts to restore and maintain ecological connectivity", and the need for "agencies within their jurisdictions to elevate ecological connectivity, conservation, and restoration in their activities."

This report responds to the need to consolidate a wealth of information and data from projects on connectivity in the NEG-ECP region (hereafter referred to as "the Region"), and to evaluate the multiple practices and methodologies used in connectivity assessments within the Region. We review the existing scope of science and projects focused on understanding and conserving ecological connectivity in the Region.

We have inventoried connectivity science projects in the Region and synthesized the results. We have identified the strengths as well as the geographic, taxonomic, and methodological gaps in the Region's ecological connectivity science and assessments. We have also provided a set of science-based recommendations emerging from this analysis.

Context

The Region comprises many biologically diverse natural wild spaces and habitats. The area includes the largest remaining area of temperate broadleaf and mixed forest type in the world. It includes large contiguous areas of forest in the White and Green Mountains of the U.S. and in the Canadian provinces of Quebec, Newfoundland, New Brunswick, and Nova Scotia. It also harbours a rich biological diversity and represents an important migratory pathway for many bird and butterfly species.

As a result of human impacts on nature, over 1 million of the world's species now face extinction, with declines in species abundances occurring in almost every known habitat (IPBES 2019, WWF 2018). Land use change in the Region takes many forms, including

deforestation, urban sprawl, the expansion of transport infrastructure, and the conversion of wetlands and grasslands into agricultural lands. All of these changes threaten ecological connectivity. The expansion of transportation networks, in particular, fragments habitats and degrades ecosystems to the detriment of biodiversity and ecosystem functions.

Climate change is also a major cause of biodiversity change and will grow in influence over the coming century. Many species inhabiting the Region are at the northern limit of their ranges and are expected to shift their distributions in response to climate change. The speed at which this occurs over the next century will be a major determinant of biodiversity change in the Region. This threat to biodiversity will impact the integrity and connectivity of natural habitat throughout the Region.

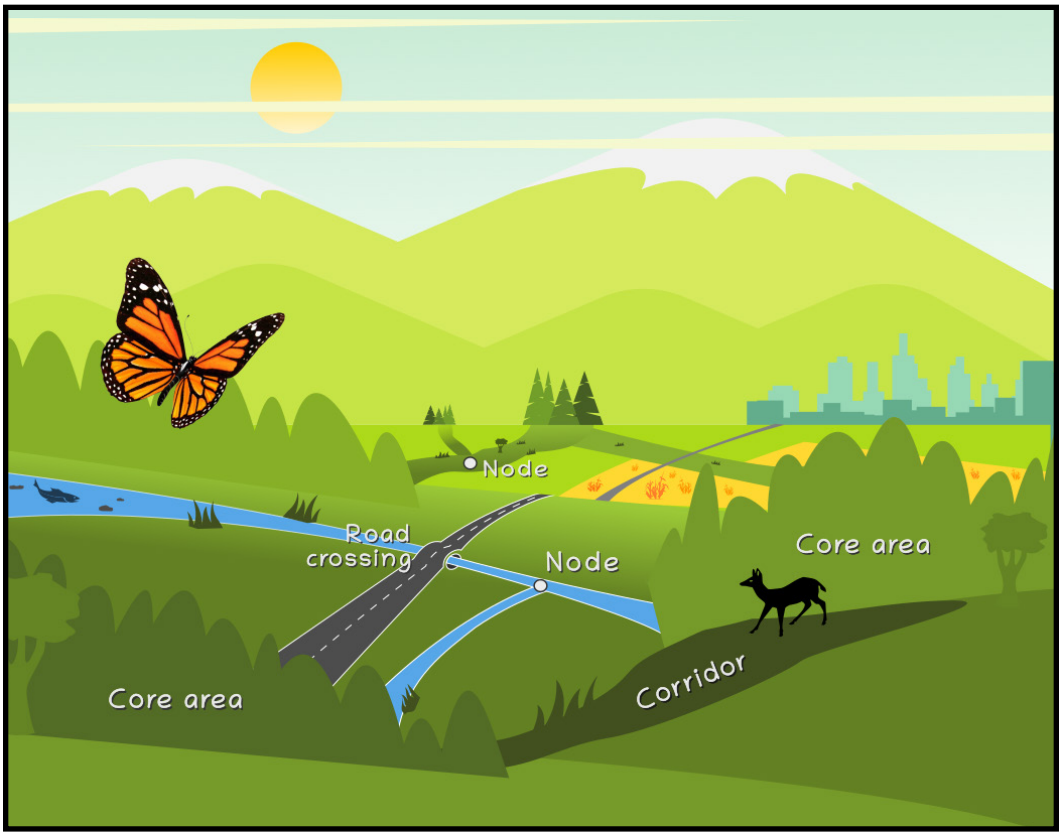
Ecological networks are a vital conservation strategy for supporting biodiversity as it responds to climate change. Changing climate conditions are forcing species to shift their ranges. Over the long term, connectivity science can respond to the risks posed by climate change by quantifying habitat and movement needs, predicting how they will change, and identify opportunities to protect large networks of habitat to safeguard connectivity and support species in the long-term.

Ecological connectivity science and solutions

The science of ecological connectivity assesses the magnitude and scale of human impacts on the landscape by focusing on disruptions to the habitat and movement needs of animals and plants. The science demonstrates that the protection and restoration of ecological connectivity can greatly mitigate some of the effects of anthropogenic landscape change on biodiversity and ecosystems.

Ecological connectivity refers to the extent to which the landscape facilitates or impedes the movement of animals and plants. At small spatial and temporal scales, the conservation of connectivity is concerned with enabling animals and plants to establish new populations or restore populations threatened with extirpation. At larger spatial scales, and in the longer-term, connectivity science focuses on conserving connected networks of populations and communities across a region, on maintaining long distance migrations that connect essential habitats, and on supporting the redistribution of species in response to climate change.

Ecological connectivity is often improved through the identification and conservation of networks of habitat and corridors. Other structural interventions, such as building road underpasses or removing barriers, such as dams, can restore or facilitate species' movements. Planning and prioritization of ecological networks typically includes the use of specialized software, data on species' habitat needs, and information on species' potential or actual movement pathways.

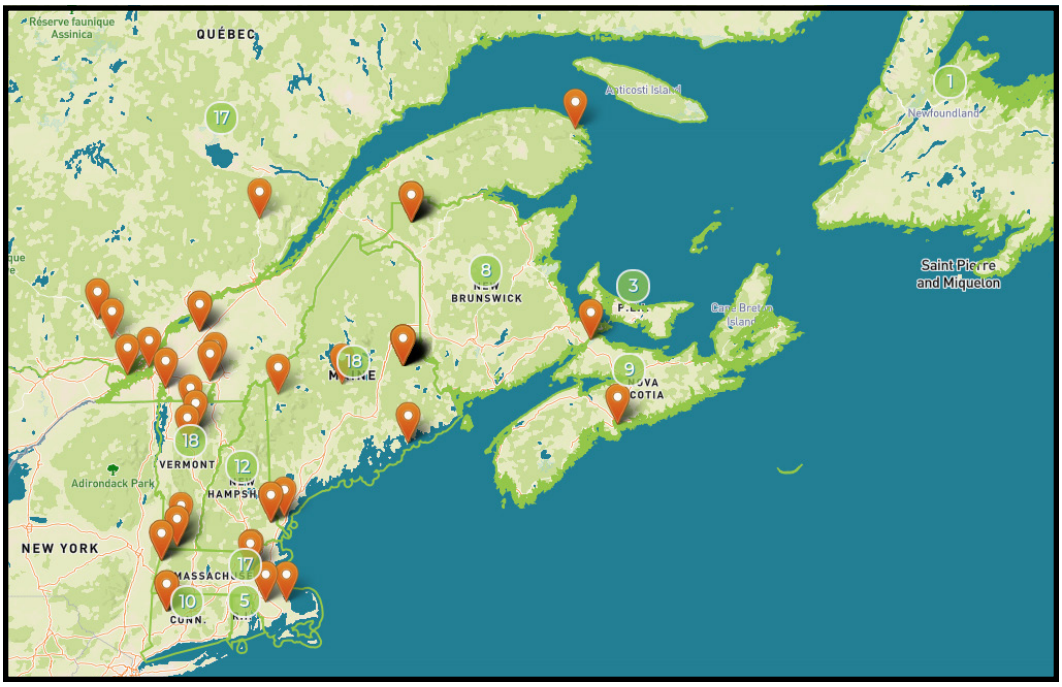


The ecological connectivity of a landscape can be assessed for many different species. Mammals, fish and insects all have different habitat needs and ways of moving through a landscape. The connectivity of a landscape is quantified by the degree to which it facilitates or impedes the movement of all organisms through aquatic (e.g., rivers and streams) and terrestrial (e.g., forests and grasslands) ecosystems. These movements are necessary to maintain viable populations in the long-term. Human forms of land use, such as roads and urban areas, are known to greatly hinder movement, increase mortality, and decrease connectivity in the short and long term. The more we build and transform the landscape, the less connected it becomes. Connectivity science can reveal solutions to mitigate human impacts on movement; these solutions include specific interventions such as the construction of road crossings for wildlife, the removal of dams, or the protection and restoration of habitat corridors between core areas of habitat. These interventions form part of a coherent strategy to design an ecological network of connected ecosystems for an entire region. Ecological networks for biodiversity conservation can be designed to allow many species to adapt to climate change and protect the resilience of ecosystems, and the many services and benefits we receive from them.

Projects assessing connectivity in the Region

We catalogued a total of 58 projects from the Region, using the Ecological Connectivity web portal (**https://ecologicalconnectivity.com**). These represent a rich foundation of knowledge and information. We identified six projects that cover large extents of the Region. Among those, three stand out for applying similar methods across the Region, and using a thorough analysis framework: Staying Connected Initiative, The Nature Conservancy's Resilient and Connected Landscapes,, and Nature's Network. This ensemble of projects offers a solid and rich foundation on which to develop future connectivity science analyses and conservation efforts in the Region.

Most projects in the Region focus on individual states or provinces and derive important conclusions for the relevant jurisdiction. These projects are mostly tools and resources to manage connectivity. The catalogued reports for these protects identify priority habitats, linkages, and sites for wildlife road crossings in their respective areas; some of these projects have compelling interactive tools for land managers to inform sustainable development.



Map showing coverage of conservation science projects in the Region (https://ecologicalconnectivity.com/explore). Green circles indicate the number of projects in each state or province, including projects that cover entire states or provinces and cross-boundary projects. Orange markers indicate more localized connectivity conservation efforts.

Large portions of the Region are covered by sophisticated connectivity science. These projects find that 20 to 40% of the Region's terrestrial landscape makes up an essential network of core habitats and linkages needed to preserve connectivity. In addition, 30% of both lakes and streams are essential landscape features supporting connectivity. Moreover, 50 to 80% of these essential areas are insufficiently protected from human development. Many current linkages and projected climate corridors important for dispersal in the changing landscape of the Region are in urgent need of protection to ensure long-term resilience.

Certain taxonomic groups and ecosystem types of the Region are not well covered by existing initiatives. Temperate forests and aquatic systems are generally well represented by existing analyses, while boreal forest and grasslands are less well studied. Some groups of species, such as insects and other invertebrates, require special attention.There is an opportunity to address this under-representation by conducting an integrated connectivity analysis of terrestrial and aquatic ecosystems for the entire Region.

Future research on connectivity in the Region could add new analytical methods and models to ensure more robust investment in conservation based on an understanding of the Region's social and ecological future. These include model-based projections of change in connectivity due to land use and climate change at multiple scales. Uncertainty about the impact of these factors in different parts of the region can be addressed using scenario-based projections of the Region's future. Scenario analysis can support an adaptive management framework for connectivity conservation planning in the Region.

Recommendations

Building on existing efforts and collaborations, we offer five recommendations to strengthen connectivity conservation and science-based assessments of connectivity in the Region.

Perform regular assessments to evaluate the changing state of connectivity at the scale of the entire Region.

Several comprehensive ecological connectivity studies carried out over a significant portion of the Region can be used as strong building blocks for further analyses. We recommend expanding some of these studies to cover the entire Region, including the southern New England states, Newfoundland and Labrador, and northern Quebec. A Region-wide analysis would allow us to better understand the possible connectivity pathways between northern New England and

Gaspésie and New Brunswick to the East, and with the forests of the Laurentians and northern Québec to the West and North. Performing assessments at regular intervals would allow for the detection of changes and potential thresholds in connectivity metrics and allow for the re-evaluation of the efficacy of conservation measures in place to protect or restore connectivity.

Support the open sharing of methods and data for collaboration at the scale of the Region.

The development of the Ecological Connectivity online portal has helped to address the need for better sharing of information, reports, and methodologies among different stakeholders. We recommend continued development of this platform and a focus on open-source technologies to facilitate sharing analysis workflows. Explicit partnerships can be established between decision makers/ministries and the scientific community, so that data sources used to design and monitor connectivity networks are better integrated. Data pipelines for connectivity assessments and monitoring should be used to support species distribution models, occurrence data, statistical analysis, and prioritization tools for connectivity assessments.

Integrate analytical methods and adopt a multi-scale and multi-ecosystem approach that supports prioritization and the implementation of an ecological network for conservation across jurisdictions and scales.

Combining multiple methods will produce more robust assessments that account for uncertainty in habitat preferences, movement ecology, and future environmental conditions. Multi-scale connectivity assessments can simultaneously guide conservation at the local scale, while identifying constraints and opportunities for conservation across the entire Region. We further recommend the adoption of multi-species assessments combined with landscape geodiversity to develop prioritization areas that are not only suitable for the target species habitat and movement, but that also contain a diversity of landforms and topographies, thereby potentially capturing important habitats for many different groups of organisms.

Incorporate uncertainty into assessments and future plans for a regional ecological network for conservation. Important uncertainties relating to climate change and land use change can be addressed via scenario-based analysis and planning.

Connectivity conservation planning and scientific connectivity assessments must deal with various sources of uncertainty. To support efforts to gather new information and data,

we recommend reporting and evaluating these sources of uncertainty. One optimistic avenue for this is scenario-based planning which has the potential to: **1)** Allow the explicit inclusion of broad uncertainties in future land use and climate in the decision making process; **2)** Allow corridors and connected network designs to be more robust to changes in climate and land use; and **3)** Identify sets of solutions—rather than single corridor or networks designs—founded on an adaptive approach to managing connectivity in an uncertain world.

Develop a connectivity monitoring network to support the adaptive management of the region's connectivity conservation.

We recommend the implementation of a connectivity monitoring network, building on existing initiatives, to track trends in connectivity across the Region. Monitoring will fill data gaps across the Region and support validation of the models. A combination of direct and indirect methods can be used to assess how organisms use the ecological network. For example, functional connectivity can be estimated from data obtained by camera traps, GPS collars, eDNA, and genetics. Remote sensing can help assess the ecological integrity of the network and identify threats from land use change and development of transport networks. Monitoring can also support action on the ground to protect core areas and linkages across the Region.

Conclusions

The long-term resilience of the Region's biodiversity and ecosystems, along with the processes that support the many services and benefits we derive from them, depend on the conservation of ecological connectivity. Past and ongoing research and projects reviewed by this report have established an exceptional knowledge base for the Region. Future efforts can build from this rich body of work to extend analysis of connectivity to important under-represented natural areas, identify missing linkages, and design an ecological network for conservation that is robust to climate change, land use change, and other threats to the integrity of Region's ecosystems. A regional ecological network for conservation would be a highly effective nature-based solution for the people and wildlife living in the Region.