CENTER for LARGE LANDSCAPE CONSERVATION

Integrating Connectivity into State Wildlife Action Plans (SWAPs):

Threats, Actions, and Recommendations

By:

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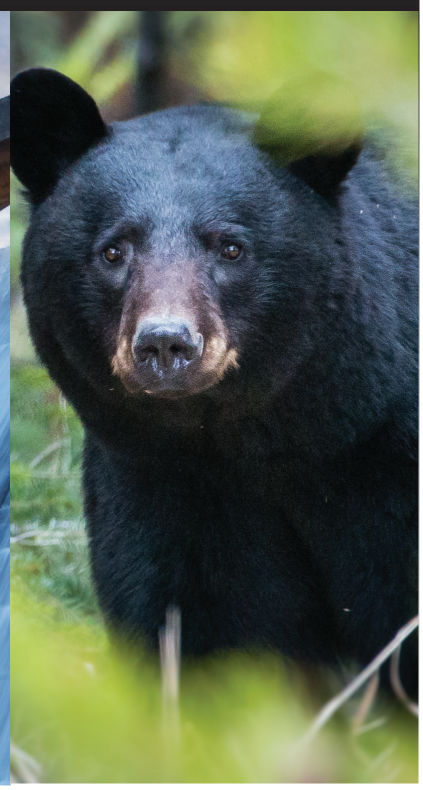

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Introduction

Ecological connectivity (or simply "connectivity") refers to the capacity of landscapes and seascapes to allow species to move freely and for ecological processes to function unimpeded.[1] Connectivity is fundamental for biodiversity conservation and human well-being in an era of accelerating environmental change.[2] Connectivity conservation involves mitigating barriers to species movement, such as roads or dams, and maintaining and restoring landscape features, such as corridors or linkage areas, that facilitate species movement.[3] As the landscape becomes increasingly fragmented, maintaining or restoring connectivity allows species to move safely between intact habitats to access food, water, and mates on a daily, seasonal, and annual basis. Over extended periods, connectivity maintains genetic diversity by preventing populations from becoming isolated and allows species to shift their ranges to track suitable conditions as the climate changes.[2] Connected landscapes also benefit human well-being by supporting critical ecosystem services such as carbon sequestration, clean water, and crop pollination, and improving human safety through wildlife crossings over or under roads.[4]

Over the past two decades, there has been a wave of legislation and executive action at state and federal levels to improve aquatic and terrestrial connectivity and reduce wildlife-vehicle conflict.[5] At the state level, 20 states have passed connectivity legislation since 1999, including more than 83 individual pieces of legislation.[6] Interest in connectivity policy has increased significantly since the passage of the Infrastructure Investment and Jobs Act, which allocated tens of billions of dollars for ecosystem restoration—including $350 million for wildlife crossings, and $1 billion for culvert-related barriers to anadromous fish passage.[7] Connectivity conservation is also the cornerstone of the Biden Administration's America the Beautiful initiative and is the focus of recent guidance from the White House's Council on Environmental Quality.[8]

Opportunities for accelerating connectivity conservation are also associated with Recovering America's Wildlife Act (RAWA), should it come to pass. In its current form, RAWA would provide more than $1.4 billion of funding each year to states and tribal entities for the management of fish and wildlife species of greatest conservation need. While RAWA failed to be enacted in 2022, support for the law is growing, and many within the conservation community anticipate its passage in the coming years.

Despite the increased attention from policymakers and the public, there are several challenges to conserving connectivity in practice. Identifying key areas for connectivity conservation at appropriate scales can be complex and typically requires significant investment and expertise in data collection and modeling[9]. And because ecological connectivity spans jurisdictions, coordination and collaboration across sectors and landscapes is essential.[10] Another source of complexity is the variety of interventions and measures—including regulations, education and outreach, and financial incentives—that must work together seamlessly to connect landscapes and people.[11]

For these reasons, State Wildlife Action Plans (SWAPs) are fundamental for advancing connectivity conservation in the United States.[12] SWAPs are comprehensive wildlife conservation plans that must address the following eight elements:[13]

1. Species abundance and distribution
2. Relative conditions of key habitats
3. Threats to species and habitats
4. Proposed conservation actions
5. Monitoring needs
6. Procedures to review the plan
7. Partner coordination
8. Public participation

State wildlife agencies are required to complete SWAPs to qualify for funding from the State Wildlife Grants program (SWG), established in 2000 to support the conservation of at-risk species and their habitats.[14] Since the establishment of the SWG program, SWAPs have become recognized as "conservation blueprints" that compile the best available conservation science and provide a platform for collaboration and coordination among diverse governmental and non-governmental partners.[15] States must also update SWAPs every ten years, creating a benchmark against which agencies and partners can track progress and innovations in conservation planning.[12]

To support integrating connectivity into SWAPs, the Center for Large Landscape Conservation reviewed SWAPs from the 2015 revision cycle and interviewed state wildlife planners. The intent of this report is to provide SWAP planners and partners with a comprehensive "menu" of actions and best practices that can advance connectivity conservation in the face of diverse threats. It is important to note that our review was based on the content of the SWAPs, and it does not reflect the efficacy of their implementation, or the full range of connectivity conservation activities that state wildlife agencies engage in outside of their SWAPs. In the following sections, we discuss our research approach, provide an overview of connectivity actions for specific threats, and conclude with recommendations for developing and implementing connectivity actions.

Approach

Our research approach involved document analysis and semi-structured interviews with key informants from state wildlife agencies. To identify and characterize the scope of connectivity actions in SWAPs, we first reviewed proposed conservation actions (required component #4) from all 50 states from the 2015 SWAP revision cycle. We read each proposed conservation action and associated contextual text to identify and compile all the unique actions that specifically addressed understanding, maintaining, restoring, or mitigating barriers to ecological connectivity. We did not use a word search function because many actions addressing connectivity did not use terminology such as "corridors" or "linkages."

After compiling our dataset of connectivity actions, we applied codes using Dedoose qualitative analysis software to facilitate thematic analysis. To evaluate the range and focus of different actions, we categorized connectivity actions using Salafsky et al.'s (2008)[16] classification framework for threats and actions, as recommended by the Association of Fish and Wildlife Agencies (AFWA) in their 2012 best practices guide.[17] The framework is hierarchical, with three different classification levels for threats and actions; first-level entries (e.g., transportation and service corridors) are subdivided into second-level entries (e.g., roads and railways), and finally, specific third-level entries (e.g., highways).

We first coded connectivity actions by the first-order threat they address (Table 1). For instance, actions that referenced or addressed the impacts of roads were coded under "transportation and service corridors." Cross-cutting actions that addressed multiple threats were given multiple codes, and actions for which it was difficult to discern a specific threat received no code.

Threats	
1st Level Threat	**2nd Level Threat**
Natural Systems Modification	• Fire and Fire Suppression • Dams and Water Management/Use • Other Ecosystem Modifications
Transportation and Service Corridors	• Roads and Railroads • Utility and Service Lines • Shipping Lanes • Flight Paths
Residential and Commercial Development	• Housing and Urban Areas • Commercial and Industrial Areas • Tourism and Recreation Areas
Agriculture and Aquaculture	• Annual and Perennial Non-Timber Crops • Wood and Pulp Plantations • Livestock Farming and Ranching • Marine and Freshwater Aquaculture
Climate Change	• Ecosystem Encroachment • Changes in Geochemical Regimes • Changes in Temperature Regimes • Changes in Precipitation and Hydrological Regimes • Severe/Extreme Weather Events
Energy Production and Mining	• Oil and Gas Drilling • Mining and Quarrying • Renewable Energy
Biological Resource Use	• Hunting and Collecting Terrestrial Animals • Gathering Terrestrial Plants • Logging and Wood Harvesting • Fishing and Harvesting Aquatic Resources
Human Intrusions and Disturbance	• Recreational Activities • War, Civil Unrest, and Military Exercises • Work and Other Activities
Invasive and Problematic Species, Pathogens, and Genes	• Invasive Non-native/Alien Plants • Problematic Native Plants, Animals, or Pathogens • Introduced Genetic Material
Pollution	• Household Sewage and Urban Wastewater • Industrial and Military Effluents • Agricultural and Forestry Effluents • Garbage and Solid Waste • Airborne Pollutants • Excess Energy

Table 1: Threats

We also used Salafsky et al.'s framework to categorize different types of connectivity actions. These include land and water protection, land and water management, species management, education and awareness, law, policy, and planning, livelihood, economic or other incentives, and capacity building (Table 2). We added “research and monitoring” to capture proposed actions in SWAPs that referenced research, data collection, monitoring, or modeling associated with connectivity. We also coded actions referencing internal capacity building, such as hiring staff, under the broad category of "capacity building." Again, many actions received multiple codes.

It is important to note that many coding decisions were difficult and somewhat subjective. For instance, we often interpreted the type of action based solely on the presence of verbs like "protect" or "restore." We also used our best judgment regarding what constituted a discrete action. In some cases, proposed actions were bundled in longer paragraphs with other actions. For these reasons, our quantitative figures should be considered approximate rather than definitive. The full dataset can be found here.

Conservation Measures		
1st Level Classification	**2nd Level Classification**	**Explanation**
Capacity Building	• Institutional and Civil Society Development • Alliance and Partnership Development • Conservation Finance • Organizational Development	Actions to build the infrastructure to do better conservation
Education and Awareness	• Formal Education • Training • Awareness and Communications	Actions directed at people to improve understanding and skills, and influence behavior
Research and Monitoring	• Data Collection and Monitoring • Scientific Research • Modeling and Mapping	Actions to develop the knowledge base for conservation
Law, Policy, and Planning	• Legislation • Policies, Regulations, and Planning • Private Sector Standards and Codes • Compliance and Enforcement	Actions to develop, change, influence, and help implement formal legislation, regulations, and voluntary standards
Land and Water Management	• Site/Area Management • Invasive/Problematic Species Control • Habitat and Natural Process Restoration	Actions directed at conserving or restoring sites, habitats, and the wider environment
Land and Water Protection	• Site/Area Protection • Resource and Habitat Protection	Actions to identify, establish or expand parks and other legally protected areas, and to protect resource rights
Livelihood, Economic, or Other Incentives	• Linked Enterprises and Livelihood Alternatives • Substitution • Market Forces • Conservation Payments • Nonmonetary Values	Actions to use economic and other incentives to influence behavior
Species Management	• Species Management • Species Recovery • Species Reintroduction • Ex Situ Conservation	Actions directed at managing or restoring species focused on the species of concern itself

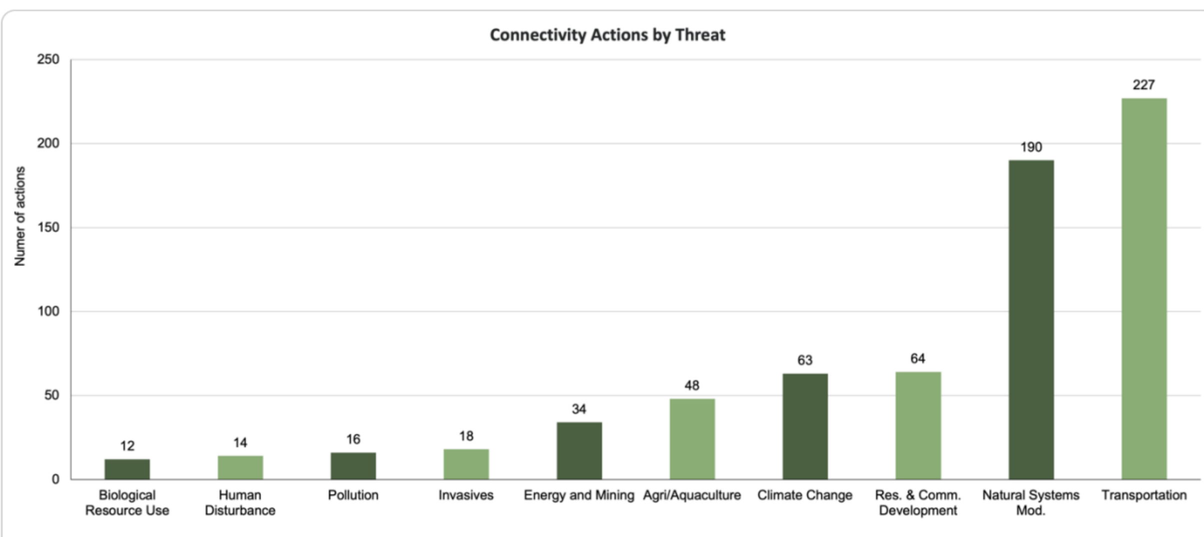
Table 2: Conservation Measures

Finally, to learn more about best practices for integrating connectivity into SWAPs, we conducted interviews with state wildlife planners who have been successful with connectivity planning or have implemented connectivity actions from their 2015 revision SWAPS. We asked respondents about best practices for applying or developing connectivity science, producing clear and specific actions, and lessons learned from implementation. Interviews were recorded, transcribed, and analyzed using Dedoose qualitative analysis software.

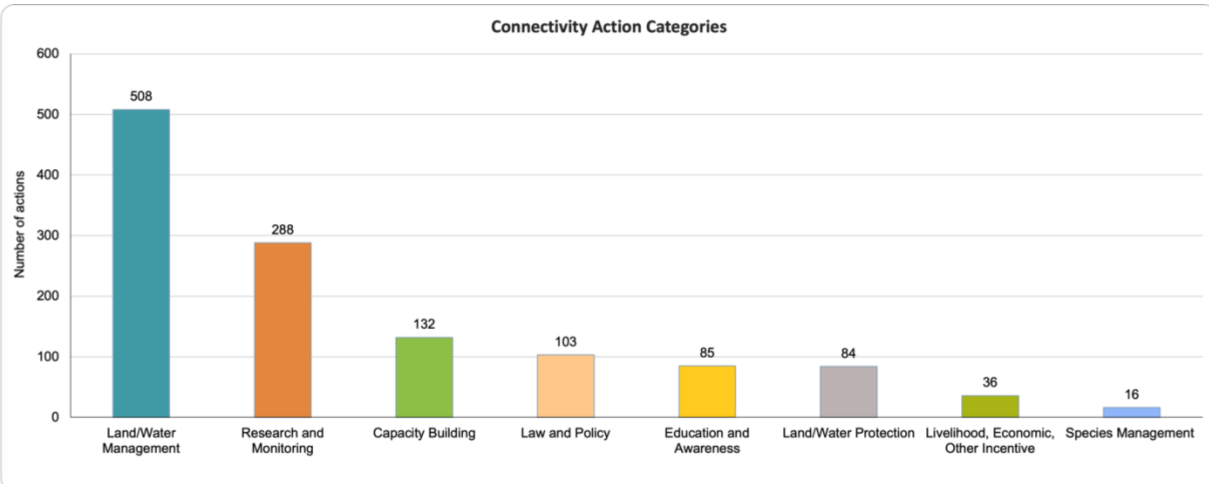
Connectivity Threats and Actions

Overview

Threat-based assessments are a fundamental component of strategic, landscape-scale conservation. By systematically assessing threats to species and habitats, planners can identify and prioritize conservation actions and engage relevant partners, including other states.[17] Unsurprisingly, we found that most actions that addressed specific threats were associated with transportation and service corridors (roads, railways, transmission lines, and shipping lanes), and natural system modifications (primarily dams, diversions, and other aspects of water management). Following these threats, a second tier of connectivity actions addressed residential and commercial development, climate change, agriculture and aquaculture, and energy and mining. We found relatively few actions that addressed invasive species, pollution, human disturbance, and biological resource use. As discussed below, we believe some of these threats should receive greater consideration for their impacts on connectivity in 2025 SWAP revisions.



We also found an interesting distribution associated with different types of connectivity actions. Over half of the actions fell into the land and water management category, followed by research and monitoring. Behind these categories, we found a second tier that included capacity building, law and policy, education and awareness, and land and water protection. We found relatively few actions associated with financial or economic incentives and only a handful of actions associated with species management.



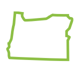
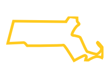
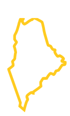
Below, we highlight findings and examples of connectivity conservation actions, organized by threat category. For each threat category, we provide an overview of the threat in the context of connectivity, observations of themes, examples of different conservation actions, and considerations for addressing each threat in 2025 SWAP revisions and implementation. Additional resources and examples for each threat are also compiled in Appendix 1.

Transportation and Service Corridors

Transportation and service corridors—roads and railways, utility and service lines, and shipping lanes—profoundly impact habitat connectivity through both direct and indirect means.[18] In addition to mortalities resulting from collisions with vehicles or infrastructure, roads and railways deter species from accessing daily and seasonal resource needs. Over the long term, roads fragment habitat and isolate populations, leading to a loss of genetic diversity.[19] Shipping lanes similarly impact marine populations through direct effects, such as ship strikes, and indirect effects associated with noise and chemical pollution.[20] Transmission lines disproportionately impact avian species populations through collision-related mortality and injuries.[21] They also fragment habitat; vegetation management associated with transmission rights-of-way can create barrier effects for many species or facilitate the spread of invasive species. However, with effective management, transportation and transmission rights-of-way can also serve as corridors for many species, including at-risk pollinators.[22] [23] [24]

Connectivity actions related to roads and railways were wide-ranging and addressed barriers to both terrestrial and aquatic connectivity. Common actions included collecting data on wildlife-vehicle collisions and barriers to aquatic organism passage to identify locations for mitigation and management and coordinating with state Departments of Transportation to integrate connectivity considerations into transportation planning. We also found several examples of site-scale actions and Best Management Practices (BMPs), such as addressing the edge effects of mowing, designing curbs and construction standards to facilitate the movement of amphibians and reptiles, and addressing "ecological traps,"[25] such as roadside ditches filled with water, which can attract wildlife and increase road mortality. Some actions also made a clear link between improved aquatic organism passage and resilient infrastructure since structures promoting species movement are more likely to weather intense storm events.[26]

We found relatively few actions that referenced transmission lines. Given the significant investment in green energy associated with the Bipartisan Infrastructure Law and the Inflation Reduction Act, SWAP planners should consider this threat carefully in their 2025 revisions. To meet its ambitious clean energy goals, the United States will need two to three times more transmission capacity—up to 200,000 miles of new transmission lines.[27]

Transportation and Service Corridors		
CAPACITY BUILDING		
	**Oregon**	Work with community leaders and agency partners to identify wildlife movement corridors and to fund and implement site-appropriate mitigation measures such as drift fences to overpasses or underpasses. In forested habitats, maintain vegetation to provide screening along open roads, prioritize roads for closure based on transportation needs and wildlife goals, and/or manage road use during critical periods.
	**Texas**	Form a multi-disciplinary ecological working group to work directly with TXDOT Regional Engineers and FHWA to identify areas of high ecological significance to avoid or minimize impacts during development of priority highway improvements and connectors. Study, identify, and include areas for focused bridge and culvert design to accommodate migratory and daily movement for wide-ranging species (pronghorn, black bear) and bat roosts; identify and suggest protective measures for water quality at important crossings at and upstream of Ecologically Significant Stream Segments; and identify significant riparian corridors and playas for avoidance.
EDUCATION AND AWARENESS		
	**Massachusetts**	Continue to educate the public on the Linking Landscapes project to encourage reporting of road-related mortality for turtles and other wildlife species.
	**Maine**	Continue to build public awareness of risks to wood turtles posed by roadways with a seasonally appropriate press release that also warns motorists to be on the lookout for turtles during spring/early summer.
RESEARCH AND MONITORING		
	**Maine**	Identify high-priority road segments/culverts for organism passage among freshwater wetlands.

Maryland	Improve connectivity of habitat within streams for mussels and host fishes by addressing poorly designed or failing culverts with State Highway Administration and the U.S. Fish and Wildlife Service. Conduct a new culvert assessment in entire Northeast to prioritize culvert work by North Atlantic Landscape Conservation Cooperative – University of Massachusetts-The Nature Conservancy [aquatic connectivity assessment].
Michigan	Research effective culvert options to allow safe movements of copperbelly water snakes between habitats.
Michigan	Work with the Michigan Department of Transportation, county and municipal road commissions, and Michigan Department of Environmental Quality to inventory road stream crossings to identify priority sites to reduce sediment inputs, and to ensure that best management practices are used during maintenance, repair, and installation of culverts and bridges.
New Hampshire	Expand collection of roadkill data. Currently, the only species monitored are deer, bear, moose and turkey. Data collection could make use of volunteers (e.g., Reptile and Amphibian Reporting Program) and those likely to encounter roadkill (New Hampshire Department of Transportation road agents).
Idaho	Continue the partnership with Idaho Transportation Department (ITD) and Federal Highway Administration (FHWA) to develop and monitor traffic volume, wildlife-vehicle collisions, and other metrics needed to identify connectivity and high-risk areas for road mortality or road crossing avoidance.
LAW AND POLICY	
Delaware	Work with the Delaware Department of Transportation to develop BMPs to integrate key habitat and SGCN conservation into landscaping, mowing, invasive plant control and other road maintenance, including preserving and restoring buffers and reducing edge effects.
Connecticut	Develop standards for road crossings and road designs (e.g., curbs, box culverts) to reduce the mortality of GCN herpetofauna species.
New Jersey	Develop policies that minimize wildlife road mortality through: 1) Requiring the integration of wildlife passages into all new and repaired roads, in particular those areas that will connect SGCN habitats, 2) Requiring current fish/wildlife passages to be improved and maintained in perpetuity, 3) Supporting seasonal road closures, in particular for unimproved roads, and 4) Supporting projects that work to improve connectivity of SGCN habitats such as land conservation through acquisition or other means.
Delaware	Work with utilities to develop BMPs to integrate key habitat and SGCN conservation into corridor maintenance, including controlling invasive species, preserving and restoring buffers and reducing edge effects.

LAND AND WATER MANAGEMENT	
New Mexico	Complete mitigation to facilitate aquatic and terrestrial (including xeric riparian) habitat linkages across roads or other linear development features for SGCN. These include modifying barrier fences along roadways, and constructing road crossings that are permeable to SGCN. Monitor the efficacy of mitigation and initiate any identified maintenance and improvements. Potential collaborators: BLM, DOD, SLO, local governments, private industry.
New Jersey	Remove drainage ditches adjacent to roads to decrease the attraction for amphibians, reptiles, and small mammals, and thereby minimize road mortality of such species (e.g., amphibians, snakes, turtles, small mammals).
Vermont	Remove or replace culverts and dams that impede passage of aquatic SGCN in high-priority areas. Measure: Miles of SGCN habitat with restored connectivity.
Georgia	Enhance habitat in utility corridors for use by migratory birds and pollinators. For some migratory bird and pollinator species (e.g., painted bunting and ruby-throated hummingbird), Georgia may be their first significant landfall during spring migration.
Florida	Work with utility companies to mark or bury power lines, when appropriate, to reduce bird mortality caused by collisions.

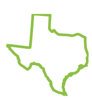
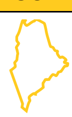
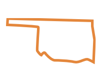
Natural Systems Modifications

Natural system modifications, such as water resource management and fire suppression, degrade habitats and ecological processes to benefit human welfare. Unsurprisingly, most connectivity actions in this category addressed dams, diversions, flood control, and other aspects of water management. Dams and diversions significantly impact connectivity and are among the primary threats to aquatic species in the United States.[28] They impact longitudinal connectivity for aquatic species upstream and downstream of rivers, lateral connectivity from the river's main stem across the floodplain, and vertical connectivity from the river to the underlying water table. These changes negatively affect aquatic species' access to spawning and foraging habitats in side channels, the resilience of riparian corridors used by terrestrial species, and wetlands used as stopover habitats by avian species.[29]

Connectivity actions in this category called for creating dam-removal task forces, inventorying barriers to aquatic organism passage, removing or retrofitting dams and installing fish ladders, maintaining or restoring flow regimes to benefit riparian and wetland habitats, protecting free-flowing rivers, participating in federal regulatory processes, and providing training and outreach to water resource managers and private landowners.

While the primary species of interest were fish and freshwater mussels, some actions also referenced managing water levels to provide stopover habitat for migratory birds. On both the East and West Coasts, several actions specifically emphasized the importance of using decision-support tools and cost-benefit analyses to prioritize opportunities for dam removal,[30] which is occurring more frequently on larger rivers.[31] A common theme across connectivity actions for water resource management was balancing the benefits of improved aquatic connectivity with tradeoffs such as non-native species incursion and economic impacts to water resource users.[32]

Beyond water management, a few connectivity actions in this category addressed fire suppression and shoreline hardening. Given the significant investment in forest restoration and fuel management associated with the Wildfire Crisis Strategy, planners in the western United States should evaluate if there are opportunities for integrating connectivity considerations into forest restoration and fuel management activities that seek to mitigate the effects of suppression. States such as Colorado and Arizona, for instance, have made conserving wildlife corridors a key objective in their Shared Stewardship Agreements with the US Forest Service for forest restoration. Connectivity data was also integrated into the USFS Climate Risk Viewer, which supports climate-informed forest planning.

Natural Systems Modifications		
CAPACITY BUILDING		
	**Texas**	Form a working group with adjacent Texas Blackland Prairie and Gulf Coastal Prairies and Marshes aquatic and terrestrial ecologists to identify river rehabilitation goals in/adjacent to undammed stretches below last impoundment to the estuaries to evaluate/implement instream flow recommendations; improve the quality, timing, and seasonality of releases, improve riparian restoration, and increase connectivity to improve resilience to climate change.
	**Louisiana**	Partner with LCCs, JVs, USFWS, NRCS, and other interested groups to encourage landowners to manage water levels to provide habitat for shorebirds during migration; acquire and manage properties for shorebird use in underrepresented areas.
EDUCATION AND AWARENESS		
	**Maine**	Provide outreach and education to dam operators on ways to facilitate SGCN fish passage at dams.
RESEARCH AND MONITORING		
	**Oklahoma**	Research alternative methods of flood control such as levee removal or wetland restoration within floodplains to reduce the need for flood control impoundments that alter flows and block fish passage.
	**Delaware**	Complete a cost/benefit analysis of dam removal. Consider the needs of other uses or values (historical, water supply). Investigate other options to solve issues (i.e., fish passages, etc.).
	**Illinois**	Develop a comprehensive approach for identifying barriers (e.g., dams, levees, dewatered reaches) that fragment aquatic habitats and no longer provide essential services.

LAW AND POLICY

Massachusetts

Work through the FERC relicensing process to mitigate the effects of hydroelectric dams. Specifically, relicensed projects should have adequate upstream and downstream fish passage and should operate as run-of-river (no peaking) to provide suitable habitat for fish (Murchie et al. 2008) and invertebrates (Layzer and Madison 1995; Layzer and Scott 2006).

Delaware

Programs to restore stream connectivity and improve or maintain flow rates and water quality must be expanded. Examples of conservation at this scale are the Delaware Water Resources Registry and the Delaware Bayshore Initiative.

New Hampshire

Coordinate and provide guidance on dam management to improve wildlife connectivity and habitat resilience. NHFG should continue to participate in Federal Energy Regulatory Commission (FERC) relicensing, which addresses issues with water level management and fish passage at existing hydropower dams. Wildlife managers should explore ways to be more involved in water release regimes and scheduling, especially in areas with sensitive species. In the future, a central program office in a single agency to coordinate statewide flow regimes would be extremely helpful and would help bridge the gap between researchers working on ways to better manage flow and those responsible for dam management. The River Restoration Task Force, a group of experts from government agencies and nonprofit conservation organizations, was convened in 2001 to help coordinate dam removal projects in New Hampshire.

LAND AND WATER MANAGEMENT

Alabama

Fish passage should be provided at Elba Dam on the Pea River to provide Gulf Sturgeon and Alabama Shad access to historic habitat and allow free movement of mussel host species.

Oregon

Continue work with the OWEB, ODOT, ODF, USFS, BLM, counties, local municipalities, irrigation districts, and other partners to inventory, prioritize, and provide fish passage at artificial obstructions, enhancing current work done by the ODFW Fish Passage Task Force to expand implementation of fish passage priorities.

California

Manage dams and other barriers by reviewing potential cost/benefit of modifying or removing dams that block access to significant amounts of high-quality salmonid spawning and rearing habitat and modifying or removing Cape Horn Dam and Scott Dam from the upper Eel River, Dwinnel Dam on the Shasta River, and dams from upper Klamath River.

Residential and Commercial Development

Residential and commercial development is a leading cause of habitat fragmentation in the United States.[33] Low-density suburban and exurban development has an outsize impact on wildlife movement,[34] while higher-density urban areas pose persistent barriers for a wide variety of taxa. At the same time, a growing body of research has highlighted the benefits of connectivity-friendly planning and development design measures, such as green space corridors, which also provide important benefits for people.[35]

Connectivity actions in this category called for connectivity mapping in developing areas, state wildlife agency participation in land use planning processes, outreach and engagement with local government officials, and collaboration with land trusts to acquire easements. In urban areas, conservation actions included minimizing avian collisions with structures, connecting recreational waterways and greenways for people and wildlife, and managing parks and vegetation to provide "stepping stone" habitat.

Connectivity actions that address residential and commercial development should also receive careful attention from SWAP planners. Following increased attention at the federal and state levels, connectivity conservation is emerging as an important policy issue at the local level. Examples of local connectivity policies and planning measures are increasing, as are resources and guidance for implementation. And state wildlife agencies typically have a crucial role in providing consultation and guidance to local governments[36] (see Appendix 1).

Residential and Commercial Development

CAPACITY BUILDING

Illinois

Work with local jurisdictions to develop or redevelop using “conservation design” principles to establish neighborhood/community-scale open space and landscape linkages and trails for wildlife and humans. Connect to large natural habitats.

South Carolina

Encourage responsible land use planning throughout South Carolina that ensures the protection of natural resources. To do this, an urban biologist is needed to collaborate with municipalities and communities to reduce the impacts of development. This can be accomplished by assisting local governments in drafting meaningful comprehensive plans, as they relate to the Natural Resources section of local comprehensive plans. Other ideas include:

a. Greenways and “green space” that also function as wildlife corridors
b. Creation of a “green growth” manual for municipalities, including natural resource-friendly ordinances and incentives for green growth

EDUCATION AND AWARENESS

New Jersey

Provide educational resources, training programs, and on-the-ground guidance to municipalities, land developers, and other land managers and private landowners about the importance of leaving vegetation in place, especially along riparian areas and wildlife movement corridors.

Michigan

Support and expand programs that reduce migratory landbird collisions with manmade structures. For example, expand Project Safe Passage: Great Lakes to safeguard migratory birds in the urban environment.

RESEARCH AND MONITORING

Georgia

Create a map to help guide land acquisition and identification of greenways and wildlife corridors. The land trust community could use it to prioritize local protection projects and grant programs. Include some priorities on the map that were identified by The Nature Conservancy. Coordinate with the Oconee Rivers Greenway Commission and other local planning groups to incorporate conservation of wildlife corridors in local greenspace efforts.

LAW AND POLICY

Maryland

Site housing developments in a manner that minimizes fragmentation of large forest blocks and impacts to migratory stopover hotspots by establishing zoning laws and adjusting relevant policies.

Vermont

Participate in development-review processes to reduce negative impacts of development near wetlands and ensure that projects don’t disrupt riparian connectivity.

LAND AND WATER MANAGEMENT

Illinois

Protect and expand migratory stopover sites to increase proximity or connectedness; promote structural and successional diversity through management actions; and improve quality by using and promoting appropriate and beneficial trees, shrubs, and plants, such as those identified by Audubon-Chicago Region. Work with municipal planners, park and forest preserve districts, and others.

LAND AND WATER PROTECTION	
Washington	Use landowner agreements, conservation easements, and land acquisitions to protect [grizzly bear] dispersal habitats from development. Engage in local and state planning for roads and other large infrastructure.

Agriculture and Aquaculture

Agricultural lands are particularly important for connectivity conservation because they comprise nearly half the total land cover in the conterminous United States and play a crucial role in species movement and ecological processes.[37] Because intensive crop production and other agricultural practices create significant movement barriers for various taxa, connectivity-friendly practices such as low-intensity and diversified production, wildlife-friendly fencing, and prairie strips[38] are vital for conserving ecological connectivity.[39] Aquaculture operations can detrimentally impact the movement of aquatic and avian species dependent on coastal and offshore habitats.[40]

SWAP connectivity actions related to agricultural threats included using acquisitions and easements to protect land, providing financial incentives for agricultural management activities that benefit species movement, and conducting outreach and training with private landowners on best management practices for conserving connectivity. We found only two actions that addressed aquaculture. They called for developing BMPs and incentivizing aquaculture producers to integrate connectivity considerations into aquaculture operations.

Agriculture is another threat category that should receive careful consideration from wildlife diversity planners, especially given federal funding opportunities and new connectivity mapping products.[41] The US Department of Agriculture, leveraging funding from the Farm Bill and the Inflation Reduction Act, recently committed $500 million over five years to wildlife conservation through its Working Lands for Wildlife program. Connectivity has also been a focus of investment in the NRCS Regional Conservation Partnership Program, which in 2023 awarded $216 million to 16 projects to protect and restore wildlife corridors. Farm Bill funding and new federal initiatives provide important opportunities for conserving pollinator connectivity in agricultural landscapes.

Agriculture and Aquaculture	
CAPACITY BUILDING	
Oklahoma	Provide grants or cost-share funding to pay landowners to restore oak woodlands or shrublands on retired crop fields and pasture land. Restoration efforts should be focused on tracts that can help to expand or connect the remaining tracts of woodland habitat.
EDUCATION AND AWARENESS	
Oklahoma	Provide technical assistance to landowners to encourage grazing practices that minimize fencing and increase the structural diversity of rangelands.
LAW AND POLICY	
New Jersey	Incorporate aquatic habitat connectivity and water quality/effluent standards into local and state aquaculture plans and BMPs.
LAND AND WATER MANAGEMENT	
Louisiana	Encourage planting of native species along field borders and filter strips to create habitat and improve connectivity for wildlife species (CRP practice CP33).
Kansas	Encourage the use of fences where necessary to manage riparian corridors, and otherwise conduct proper grazing management.
LAND AND WATER PROTECTION	
Florida	Conserve agricultural land through direct purchase, easements, or cooperative agreements to increase size and connectivity of core conservation areas. Utilize partners and stakeholders to determine appropriate sites.

Climate Change

Maintaining and restoring connectivity is essential for species adaptation in a changing climate. However, climate change is also a threat to connectivity. Changing temperature regimes disrupt plant phenology and the seasonal availability of food that migrating species need. Shifting precipitation patterns, drought, and floods may irrevocably alter stepping-stone wetland habitats for avian species and hydrologic processes essential for the movement of aquatic species. Climate-driven extreme fires can drastically alter movement paths for forest obligates.[42] Above all, climate change is a cross-cutting “force multiplier” that interacts with and accentuates other threats.[43]

Climate change connectivity actions included research to understand the impacts of climate change on species and habitat movements and addressed species’ shifting ranges. We found several actions that addressed sea level rise and some that addressed elevational range shifts. Most of the actions in this threat category fell into the research and monitoring category, which may reflect the considerable uncertainty associated with climate change impacts. Climate refugia was also identified as an important consideration for connectivity actions—a concept gaining increasing significance in conservation planning.[44]

Moving forward, SWAP planners should ensure connectivity conservation is “climate-wise” for the long term by conducting broad-scale assessments and considering factors such as climate gradients and climate analogs when developing spatially explicit strategies for connectivity conservation.[45]

Climate Change

EDUCATION AND AWARENESS

Maine

Assist municipalities in identifying areas that will allow coastal habitats to migrate inland as sea level rise occurs.

RESEARCH AND MONITORING

Connecticut

Continue to incorporate new guidance and information from the Northeast Climate Science Center at the national, regional, and local levels to implement actions to enhance stability, connectivity, and habitat health so GCN species can adapt to climate change. Measure: Number of actions implemented that enhance stability, connectivity, and habitat health so GCN species can adapt to climate change.

Pennsylvania

Assess and prioritize critical connectivity gaps and needs across current conservation areas, including areas likely to serve as refugia in a changing climate.

LAW AND POLICY

Delaware

Identify beach and dune system inland migration areas and conduct land use planning to allow for habitat movement.

LAND AND WATER MANAGEMENT

Utah

Identify and maintain wildlife migration corridors, and protected buffers around populations of SGCNs that may need to move up or down in elevation.

LAND AND WATER PROTECTION

Vermont

Protect large habitat blocks, riparian habitats, and climate refugia, and promote landscape integrity and connectivity to facilitate the movement of species across habitats based on the VFWD report "Vermont Conservation Design: Maintaining and Enhancing an Ecologically Functional Landscape" (Sorenson et al. 2015), the Aquatic Organism Passage program, River Corridor Planning, and other conservation plans.

Energy Production and Mining

Energy production and mining activities often have significant environmental impacts on connectivity. While the fragmenting effects of oil and gas development on species movement are well documented, threats to connectivity from renewable energy development are anticipated to increase exponentially in the coming years because of federal and state policies. To replace today's non-renewable energy capacity, a wind-heavy and less land-intensive energy mix (75% wind, 25% solar) would require more than 4,000 square miles of new land.[46] As a result, integrating connectivity considerations into renewable energy siting and long-term mitigation is fundamental for species conservation in the 21st century.

Connectivity actions in this category addressed onshore and offshore energy development, renewables, and fossil fuels. Key actions included researching and monitoring the impacts of energy development on migratory species, using connectivity models and data to identify optimal locations for facility siting, integrating connectivity information into environmental reviews and permitting processes, and developing and implementing connectivity BMPs in partnership with utilities.[47]

Moving forward, states with expanding renewable energy development should prioritize actions such as working with partners to integrate connectivity data and BMPs into energy development processes. The Nature Conservancy's Site Renewables Right and Georgia's Low Impact Solar Siting Tool are platforms for integrating multiple data sources, including habitat connectivity, to inform energy siting decisions. Vermont Fish and Wildlife also uses connectivity layers in its conservation design to inform regulatory reviews for renewable energy development. Connectivity datasets and state agency expertise are also critical for informing rapidly expanding energy development and compensatory mitigation on federal lands.[48]

Energy and Mining

RESEARCH AND MONITORING

Maine	Improve understanding of effects of energy development on bird and other SGCN use of migration corridors in intertidal and subtidal habitats.
Maryland	Identify the relative importance of Appalachian ridgetops as migratory corridors for golden eagles to assess risk from wind power developments.
New Jersey	Conduct monitoring at constructed wind farms (within or outside of NJ) to assess the impacts on migratory species (birds, bats, insects) and determine if NJ's land use planning efforts and/or smart-growth plans need to be revised.
Nevada	Support and advocate technological research intended to develop non-lethal wind turbine designs to minimize collision mortality of raptors, other migratory birds, and bats.

LAW AND POLICY

Georgia	Steer [wind energy] projects away from the areas of highest wildlife diversity. Consider potential shifts in wildlife ranges due to climate change.
Maryland	Site industrial wind development in a manner that minimizes both direct (e.g., bird strike, habitat loss) and indirect (e.g., habitat fragmentation) impacts on SGCN and their habitats.
New Mexico	Minimize the impact of energy development and mining, especially habitat fragmentation, on SGCN. This includes mitigating the impact of renewable energy development projects, such as solar power plants (Lovich and Ennen 2011) and geothermal development, on wildlife. Potential collaborators: BLM, EMNRD, NMED, SLO, and private industry.
Delaware	Work with energy companies to develop standards for the placement of wind energy towers to avoid SGCN nesting colonies, roosts, migration routes, movement corridors, and other critical areas.
New Jersey	Use the best available science (species data, habitat present, wind farm layout options, wind blade impacts on migratory species, location of migration routes, etc.) when conducting regulatory reviews of proposed wind farm projects to minimize impacts on migratory and resident wildlife and reduce habitat fragmentation.

LAND AND WATER PROTECTION

Nevada	Maintain functional connectivity between existing intact Mojave shrub habitats and northward extensions of Mojave shrub into new regions, particularly for small mammals and reptiles with a particular focus on the cumulative impacts of habitat conversion associated with the development of solar energy generation fields.

Biological Resource Use and Human Intrusion and Disturbance

Biological resource use threats relate to the consumptive use of "wild" biological resources, such as hunting, gathering, logging, and fishing. Impacts from human intrusion and disturbances are associated with the non-consumptive uses of biological resources, such as recreation. We found few connectivity actions that referenced threats associated with biological resource use. Those we did find focused on timber harvesting, and they emphasized the importance of developing and implementing standards and best management practices for connectivity. Likewise, the few actions we found on human intrusion and disturbance addressed the impacts of motorized or non-motorized recreation.

Over the past ten years, the impacts of recreational activities on wildlife have become more well-understood. Research has shown that human presence and recreational activities, which have increased significantly since the COVID-19 pandemic,[49] can significantly alter species' movement and their use of landscapes.[50] In sensitive, intact habitats with significant increases in recreation, planners should consider actions that minimize the impacts of recreation on species movement, such as seasonal closures and outreach and education.

Biological Resource Use	
LAW AND POLICY	
Maryland	Work with the forestry community to develop timber harvest BMPs for private landowners that protect wetlands and other KWHs, and, where appropriate, the surrounding forest matrix with adequate connectivity between habitats.
LAND AND WATER MANAGEMENT	
Arizona	Design forest/woodland harvesting and management strategies that promote wildlife habitat diversity and connectivity.
LAND AND WATER PROTECTION	
North Carolina	Pursue land acquisition and easements through cooperation with land trusts with an effort to increase the width of riparian buffers and create larger patches of connected habitat. Priority should be given to brown-water bottomlands, as these are the most species-rich and are more susceptible to clearcutting and other timber harvest than cypress-gum swamps (i.e., wetter sites).
FINANCIAL INCENTIVES	
Oregon	Continue to carefully plan forest practices to maintain connectivity (KCI: Barriers to Animal Movement), particularly when species vulnerable to fragmentation are present. Seek opportunities to coordinate management of public and private lands (e.g., All-Lands Approach) whenever possible to address conservation needs. Use voluntary conservation tools, such as financial incentives and forest certification to achieve conservation goals on private lands. Carefully implemented land exchanges in the Bureau of Land Management checkerboard areas offer potential to improve connectivity and habitat values.

Human Intrusion and Disturbance	
EDUCATION AND AWARENESS	
South Carolina	Educate beachgoers and boaters about the plight of beach-nesting birds and passage migrants that use Georgia beaches and offshore bars.
LAW AND POLICY	
Idaho	Recommend that roads, trails, other infrastructure, etc., be located to avoid habitat components important to seasonal wildlife use (e.g., wintering sharp-tailed grouse, migrating mule deer, etc.)
LAND AND WATER MANAGEMENT	
New Jersey	Manage beaches to divert human activity away from staging areas for red knots and other migratory shorebirds during critical periods.
Washington	When possible, close roads to vehicles during dispersal periods (e.g., ATV use on gated dirt roads) [for western toad].

Invasives and Pollution

We found few connectivity actions that directly addressed the threats of invasive species and pollution on connectivity. Both threats were most frequently referenced in the context of other threats, such as natural systems modifications or residential development. Invasive species were commonly identified as a consideration for aquatic organism passage and the management of transportation and service corridor rights-of-way. Connectivity actions that referenced pollution were often associated with water quality. We also found a few actions that addressed the impacts of light pollution on migrating species and one action that addressed the effects of noise pollution on whales.

While invasive species and pollution are often associated with other threats and should be considered a key component of integrated landscape strategies for connectivity conservation,[51] there are also contexts in which they should receive focused attention. In the western United States, for instance, invasive annual grasses are a primary threat to ecological connectivity in the sagebrush biome.[52] Researchers are also increasingly modeling connectivity for invasive species to identify strategic locations for proactive or defensive management in aquatic and terrestrial ecosystems.[53]

Light pollution is another threat that may warrant additional consideration from planners.[54] Over the past decade, researchers have illuminated the profound impacts light pollution has on avian movement at local to continental scales, and the importance of safe lighting measures, particularly in large metropolitan areas.[55] State wildlife agencies should consider supporting local governments and other partners on wildlife-friendly lighting initiatives, such as Audubon's [Lights Out Program.]

Invasives		
LAW AND POLICY		
	Delaware	Work with utilities to develop BMPs to integrate key habitat and SGCN conservation into corridor maintenance, including controlling invasive species, preserving and restoring buffers, and reducing edge effects.
LAND AND WATER MANAGEMENT		
	**Illinois**	Utilize managed connections between streams, rivers, and floodplain wetlands when such connectivity will enhance wetland values, functions, and quality and/or when the risks of wetland degradation by sediments and other pollutants, invasive species, and water level fluctuations associated with unhealthy streams and rivers can be controlled, minimized, or reversed by management intervention.
	**Nevada**	Maximize the extent of connectivity in Mojave tributary river lotic habitats through maintenance of flows and by prioritizing the location of fish movement barriers to isolate invasive species to the downstream extent practicable.
LAND AND WATER MANAGEMENT		
	**Louisiana**	Promote humane removal [of feral cats] from Barrier Islands and other migrant stopover sites.

Pollution		
LAND AND WATER MANAGEMENT		
	**New Jersey**	Reduce [marine] noise where possible, especially in [whale spp.] migration corridors and other areas of known habitat use.
	**Maryland**	Minimize lighting at industrial wind development sites to reduce mortality of migrating birds.
	**Florida**	Manage for safe lighting practices for SGCN species (e.g., migrating birds, beach mice, sea turtles, bats).

Recommendations

Our analysis of SWAPs underscores the significant appreciation state wildlife planners have for habitat connectivity. Every state had at least a few actions that addressed habitat connectivity, and several had dozens. We found a broad range of actions for conserving connectivity in the face of numerous threats. Many were innovative, smart, and actionable, and we hope that state wildlife planners and their partners will review our complete dataset for ideas and actions. Below, we conclude with recommendations for developing and implementing robust SWAP connectivity actions, organized around four cross-cutting themes: specific and actionable planning direction, connectivity mapping, communication, and capacity building.

Connectivity planning direction

Be Specific: One key finding from our review is that most connectivity actions were overly vague. While it is important to balance specificity with flexibility, most connectivity actions read more like broad goals and objectives rather than specific and realistic actions. Approximately half of the actions were sufficiently vague that it was difficult to discern the specific mechanism for conservation or the threat they were intended to address. This is problematic because vague actions are less likely to be implemented by agencies and partners. As one interviewee reflected, *"I knew from our first SWAP that […] as stakeholders began to implement it, you know, there were a number of complaints that the actions just weren't specific enough. They just felt like they really weren't sure how should they spend their resources."* With significant federal funding for connectivity conservation now available—and the potential future passage of Recovering America's Wildlife Act—developing specific and strategic connectivity actions is more important than ever. Specific and measurable actions are also essential for effective and efficient monitoring—a key goal of SWAP development.[17]

Identify a suite of distinct and complementary actions: We found many connectivity actions in our review encompassed multiple actions, such as "identify, plan, and implement." We recommend separating distinct actions and organizing them sequentially under broad goals or objectives for connectivity. Actions that establish "enabling conditions" for connectivity interventions—such as partnership development, outreach and education, and data collection and mapping—are typically prerequisites for actions that substantively achieve connectivity conservation outcomes on the ground.

Take a "sectoral" approach: State wildlife diversity planners should consider using assessments of threats to prioritize connectivity objectives and actions associated with specific sectors (e.g., transportation, energy, local land use planning). For instance, if renewable energy development is perceived to be the most pressing threat to connectivity, planners could focus on identifying a suite of actions to address impacts from both production siting (associated with the "energy and mining" category) and distribution ("service corridors").

Invest in collaborative planning processes: States with specific, spatially explicit connectivity actions invested in collaborative planning processes that engaged stakeholders at relevant scales. Interviewees said collaborative workshops were essential for generating buy-in, fostering communication with implementing partners, and identifying actionable priorities for connectivity conservation in specific geographies. Examples include:

- **Idaho** held in-person workshops in the south, central, and northern panhandle to identify specific threats, engage relevant partners, and identify feasible connectivity actions.
- **Texas** created twelve ecoregional planning units and held nine workshops involving numerous partners focused on conservation challenges in specific ecoregions.
- **New Jersey** engaged representatives from more than 45 organizations in three Action Development workshops organized around Policy, Land Preservation and Management, and Marine themes.

Connectivity mapping

Maps delineating key areas for connectivity conservation are essential for creating spatially explicit and actionable planning direction. They help prioritize locations for connectivity conservation, promote effective coordination and communication with implementing partners, and inform the efficient allocation of resources. While most states identified spatially explicit Conservation Opportunity Areas (COAs) in the 2015 revision cycle, relatively few mapped key areas for connectivity conservation. Since then, significant advancements in connectivity science and modeling have been made, and geospatial datasets have proliferated. Key recommendations for actions associated with connectivity mapping include:

Use existing regional-scale maps: Regional-scale map products, such as the SECAS conservation blueprint, the Midwest Landscape Initiative Blueprint, Nature's Network, and The Nature Conservancy's Resilient and Connected Landscapes mapping project are authoritative datasets that provide regional context for connectivity conservation. State wildlife planners should use these products as "base maps" to identify landscape priorities for connectivity conservation, additional information needs, and opportunities for cross-boundary coordination with other states. [56]

Develop new regional connectivity datasets: States should consider building on existing regional collaborations and work with partners to develop species-specific connectivity models for wide-ranging SGCNs.[57] Regional efforts could be modeled after the USGS Migration Initiative and address high-priority SGCNs, including those for which coordinated action can help preclude a listing decision under the Endangered Species Act.

Develop statewide connectivity maps: States that have not yet developed state-level connectivity maps should consider their development a priority. Authoritative statewide maps of important species movement and connectivity conservation areas are foundational for designing and implementing state legislation and administrative policy, informing local and federal land use planning, and leveraging federal funding. In developing statewide connectivity maps, wildlife planners should build on lessons learned from states that have already created them (see Appendix 2).

Use multiple lines of evidence to inform actions: In identifying spatially explicit opportunities for connectivity conservation, state wildlife planners and partners should consider information from multiple scales and sources. For example, this might involve blending "coarse filter" landscape connectivity models, "fine filter" models that depict functional connectivity for specific species, and local and Indigenous Knowledge of species movements across the landscape.

Communication and Outreach

Effective communication with various stakeholders is paramount for advancing connectivity conservation efforts. States should ensure that communication and outreach around connectivity conservation occurs during the SWAP planning process and remains a priority for SWAP implementation. Key recommendations include:

Target a variety of stakeholders:

- **Legislators and executives**: Communication and outreach with state legislators and executive staff during and after SWAP development is important for educating them on the importance and benefits of connectivity conservation actions, ensuring actions will have political support, and informing robust connectivity policymaking.
- **Agencies and NGOs**: Ongoing communication, outreach, and training with partner organizations—such as utilities, land trusts, transportation departments, and water resource management departments—are essential for developing and implementing connectivity BMPs and administrative guidance.

- **Citizens**: Public awareness campaigns around connectivity conservation and targeted outreach to private landowners are both important for securing public support and motivating connectivity-friendly behaviors.

Emphasize co-benefits: Highlighting the indirect benefits, or "co-benefits," of connectivity conservation is a fundamental component of any connectivity communication and outreach strategy. Emphasizing co-benefits promotes buy-in from different audiences, helps align interagency missions, and builds coalitions for policy change. For example:

- Communication about the human safety benefits of wildlife crossings is essential for advancing legislation and facilitating wildlife-transportation partnerships.[58]
- Restoring riparian corridors can mitigate flooding and improve water quality and quantity.
- Culverts that promote aquatic organism passage are more resilient to extreme weather events.
- In Vermont, maintaining forestland connectivity was linked with benefits for the forest products industry and tourism,[59] which helped support the passage of Vermont's connectivity-friendly Act 171 in 2016.

Use appropriate language: In developing communication strategies, planners should also consider how specific connectivity terms will be interpreted outside of the wildlife agency. Terms that are well-understood within the scientific community may be perceived differently by external partners and stakeholders. For example, wildlife staff in one state were directed to use the term "movement routes" instead of "migration corridors" because the former is less politically controversial.

Utilize working groups: Because of the complexities associated with communications and outreach, state wildlife agencies should consider forming communication working groups and leveraging partners to develop and implement strategic communication initiatives.

Capacity Building: Regional Coordination, Partnerships and Personnel

Regional coordination across state lines is critical for strategically leveraging shared resources and achieving conservation goals at landscape scales[57]. States should build on existing collaborations and work with regional Fish and Wildlife Associations to develop multi-state connectivity conservation strategies for priority SGCNs and priority landscapes important for multiple SGCNs. To advance this important goal, state wildlife planners should identify cross-state coordination as a priority action in their SWAPs or evaluate SWAP priorities to identify opportunities for cross-state coordination. For example:

- Since 2007, the Northeast Association of Wildlife Agencies has pooled resources through its Regional Conservation Needs fund to advance regional or sub-regional scale conservation strategies, such as regional aquatic connectivity analyses. It has also identified priority landscapes for conservation, including the Appalachian Corridor Highlands and Streams initiatives, for which maintaining and restoring landscape connectivity is a key goal.

At the state level, interagency and collaborative partnerships are foundational for connectivity conservation and can take many forms, such as regional associations, task forces, steering committees, and alliances. SWAP planning direction, collaborative "summits" or meetings, and initial interagency agreements often catalyze subsequent partnerships and policies. State wildlife agencies that do not yet have connectivity partnerships or dedicated staff should consider making them a priority conservation action in their SWAP. Examples include:

- The **Washington** Wildlife Habitat Connectivity Working Group (WWHCW), formed in 2007 by the Washington Department of Fish and Wildlife and the Washington Department of Transportation, has led to the development of innovative connectivity mapping initiatives.
- **Vermont** created a joint Wildlife-Transportation Steering Committee in 2007, which led to the development of guidance for integrating connectivity into transportation.
- **Oregon**'s 2006 SWAP established wildlife movement as a priority, leading to the development of the collaborative ODOT-ODFW Wildlife Movement Strategy, which helped build the foundation for OCAMP.
- **New Jersey** created the Connecting Habitat Across New Jersey (CHANJ) working group in 2012, which includes state and federal agencies, local governments, academic institutions, and nonprofit organizations. CHANJ has developed mapping products and guidance that identify key areas and actions needed for preserving and restoring habitat connectivity and which have been used to inform permitting policy.

Effective partnerships often require dedicated staff for coordination and communication. While tight budgets make investments in staffing challenging, current federal funding opportunities for connectivity conservation offer the potential for significant returns. Cross-agency staff exchanges and dedicated interagency liaison positions are another important capacity-building strategy with demonstrated results. Interviewees also emphasized the importance of dedicated capacity to support SWAP implementation and connectivity conservation over time. Examples include:

- **Oregon** hired a full-time Wildlife Connectivity Coordinator to coordinate the implementation of its connectivity assessment and mapping project.
- The **Vermont** Department of Fish and Wildlife hired full-time positions and partnered with the Vermont Natural Resource Council, a nonprofit, to help town planners integrate connectivity into town planning. Wildlife planners were also embedded in the Transportation planning department for a time, which helped support the integration of habitat connectivity into transportation goals and objectives.
- **North Carolina** recently created an MOU funding two wildlife liaison positions to inform transportation planning.

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Appendix 1. Additional Examples and Resources

Natural Systems Modifications

Capacity building: funding and partnerships

- The Fish Passage portal is a "one-stop shop" for information on fish passage funding.
- Programs with expanded eligibility for projects that improve habitat and aquatic connectivity via components related to bridges and culverts include: the USFWS National Fish Passage Program; the Collaborative-based, Aquatic-focused, Landscape-scale Restoration Program; the Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) program; the National Culvert Removal, Replacement and Restoration Grant Program; the Tribal Transportation program, the Bridge Investment program, the Bridge Formula program the Rebuilding American Infrastructure Sustainably and Equitably (RAISE), and the Forest Service Legacy Roads and Trails Remediation Program. More info from FHWA.
- Examples of states that have created interagency task forces or steering committees for fish passage and dam removal include Oregon, Maine, and New Hampshire. Maine recently received $35 million in funding for dam removal.
- NOAA: Guidance for Considering the Use of Living Shorelines
- Examples of Regional collaboratives for aquatic connectivity: Southeast Aquatic Resources Partnership and the Northeast Aquatic Connectivity Collaborative
- Eastern Brook Trout Joint Venture

Education and Awareness

- Fish Passage Restoration Success Stories

Research and Monitoring

- National Aquatic Barrier Inventory and Prioritization Tool

Transportation and Service Corridors

Capacity Building

- Center for Large Landscape Conservation: A Toolkit for Developing Effective Projects Under the Federal Wildlife Crossings Pilot Program
- Federal funding opportunities for wildlife crossings are continuously updated documents. Programs with expanded eligibility for projects that improve habitat connectivity and reduce wildlife-vehicle collisions include: the Federal Lands Transportation program, the Federal Lands Access program, the Surface Transportation Block Grants program, the Nationally Significant Freight & Highways Projects

program, the Nationally Significant Federal Lands & Tribal Projects program, the Rural Surface Transportation Grants program, the Tribal Transportation program, the Highway Safety Improvement program, the Promoting Resilient Operations for Transformative, Efficient & Cost-Saving Transportation program, the Bridge Investment program, Bridge Formula program, the National Culvert Removal, Replacement & Restoration Grants program, the Rebuilding American Infrastructure with Sustainability and Equity program, the Collaborative-based, Aquatic-focused, Landscape-scale Restoration Program, and the Forest Service Legacy Roads & Trails Remediation Program.

- Examples of interagency wildlife-transportation partnerships and coalitions:
  - Staying Connected Initiative
  - Safe Passage I-40 Pigeon River Gorge Wildlife Crossing Project
  - Virginia Safe Wildlife Corridors Collaborative
  - Colorado Wildlife & Transportation Alliance
  - Montana Wildlife and Transportation Partnership

Education and Outreach

- Vermont's Highways and Habitats is an example of an outreach and training program between Vermont Agency of Transportation and the Vermont Fish & Wildlife Department that has been fundamental for integrating connectivity into transportation planning and implementation.
- Wildlife Crossings website
- Examples of citizen science efforts include Linking Landscapes for Massachusetts Wildlife and the Wisconsin Turtle Road Crossing Initiative

Land and Water Protection

- Center for Large Landscape Conservation: Land Trusts and Wildlife Crossing Structures: A Toolkit Detailing How Land Trusts Can Contribute to Highway Infrastructure Projects for Wildlife

Land and Water Management

- Powerline right-of-way management and flower-visiting insects: How vegetation management can promote pollinator diversity
- USDOT FHWA: Pollinator-Friendly Practices on Roadsides and Highway Rights-of-Way Program
- Opportunities to Improve Sensitive Habitat and Movement Route Connectivity for Colorado's Big Game Species

Law, Policy, and Planning

- Laws and policies related to crossings and connectivity in the nation:
  - State of the States: A look at how far U.S. state habitat connectivity legislation has advanced and what is working
  - Ecological Connectivity Policy Compendium: U.S. Policies to Conserve Ecological Connectivity 2007-2021
- Examples of wildlife-friendly design, standards and BMPs for roads and railways:
  - Integrating Wildlife Connectivity and Safety Concerns into Transportation Planning Processes
  - Vermont Transportation and Habitat Connectivity Guidance
  - New Jersey Guidance for Cores and Corridors – Road Mitigation Practices

    - Species-specific BMPs for amphibians and reptiles, small and medium mammals, desert tortoise, grizzly bears.
- California High-Speed Rail Authority is undertaking wildlife movement and mitigation options

Research and monitoring

- Numerous states, tribes, and counties have recently completed wildlife crossing and connectivity assessments, including:
    - Arizona Statewide Wildlife-Vehicle Conflict Study
    - Blackfeet Nation Animal-Vehicle Collision Reduction Master Plan
    - Colorado: Western and Eastern Slope and Plains Wildlife Prioritization Studies
    - Colorado: Eagle County Safe Passages for Wildlife
    - New Jersey: Connecting Habitat Across New Jersey (CHANJ)
    - New Mexico Wildlife Corridors Action Plan
    - Teton County Wildlife Crossings Master Plan
    - Virginia Wildlife Corridor Action Plan and Wild Virginia: Virginia's Habitat Connectivity Hub
- Center for Large Landscape Conservation: West-wide Study to Identify Important Highway Locations for Wildlife Crossings
- The Summary of Western States Analyses and Efforts for Crossings and Connectivity includes lists of state and regional connectivity and/or crossings analyses for each Western state
- ROaDS (Roadkill Observation and Data System) smartphone app
    - ROaDS app used in Vermont
- Railway mortality for several mammal species increases with train speed, proximity to water, and track curvature

Residential and Commercial Development

Capacity Building

- Intertwine Regional Habitat Connectivity Working Group

Land and Water Management

- Xerxes Society: Pollinator Friendly Parks guidelines

Land and Water Protection

- Opportunities for protecting land critical for connectivity have increased significantly since the permanent authorization of the Land and Water Conservation Fund (LWCF). Habitat connectivity is a criterion associated with the US Forest Service and Department of Interior LWCF applications, and LWCF programs have been used to protect corridors in the Northeast, and Florida's Ocala to Osceola Wildlife Corridor.
- Wyoming Open Spaces Initiative: Targeting Conservation Easement Purchases to Benefit Wildlife Report

Law, Policy, and Planning

- Resources for planners and local government include:
    - Protecting Wildlife Connectivity Through Land Use Planning: Best Management Practices and the Role of Conservation Development

    - Forest Connectivity in the Developing Landscape - A Design Guide for Conservation Developments
    - Wildlife Conservation Society Adirondack Program's Make Room for Wildlife: A Resource for Local Planners and Communities in the Adirondacks
- Examples of local planning for connectivity:
    - In Colorado, Douglas County's Comprehensive Master Plan includes priority areas for connectivity and goals, objectives, and policies relating to wildlife movement corridors.
    - Teton County, Wyoming: Land Development Code Update – Natural Resource Overlay Standards (5.2.1) and Map
    - Gunnison County Land Use Resolution Sect 11-106(P210): To protect sensitive wildlife habitat areas, to protect biological field research, and to ensure that wildlife remains a part of Gunnison County's natural environment for generations to come – especially Gunnison sage grouse.
    - Clark County Nevada has a Connectivity Management Plan for Mojave Desert Tortoise

Research and Monitoring

- Staying Connected in the Northern Green Mountains: Identifying Structural Pathways and other Areas of High Conservation Priority
- Permeable landscapes for climate change adaptation in and around Boulder and northern Jefferson Counties, Colorado

Agriculture and Aquaculture

Capacity Building

- NRCS: Increased wildlife conservation funding
- NRCS: Wildlife corridors
- NRCS: Regional Conservation Partnership Program
- NRCS: Migratory Big Game Initiative
- The Fish and Wildlife Service has created a new Center for Pollinator Conservation to explore and disseminate resources and best practices for pollinator conservation, including for migratory species such as Monarch butterflies.

Education and Awareness

- Staying Connected Initiative: Management recommendations for landowners: Sustaining healthy, vibrant lands for people and wildlife
- USDA Wildlife Friendly Fencing Guidelines
- Wildlife-friendly fencing booklet for landowners

Land and Water Management

- Conservation Northwest: Virtual Fencing Overview
- Prairie strips as a farmland conservation practice
- Prairie strips support farmers' soil, water, and wildlife conservation goals

Research and Monitoring

- Conservation Science Partners has recently developed broad-scale analyses and maps of landscape and avian connectivity conservation opportunities on agricultural lands across the United States.

Energy and Mining

- Vermont Fish and Wildlife Department uses connectivity layers associated with its Conservation Design in energy development consultation and regulatory review.
- The Nature Conservancy is a leader in responsible renewable energy development. Resources and examples include: Power of Place and the Brightfields Energy Siting Initiative Mapping Tool
- At the state level, Colorado Oil and Gas Commission developed regulations for conserving mapped ungulate migration corridors which informed Colorado Bureau of Land Management's (BLM) Big Game Resource Management Plan Amendment
- BLM's Solar Energy Permitting and Program includes a Variance Protocol for Desert Tortoise connectivity habitat

Human Intrusion and Disturbance, Invasives and pollution, Biological Resource Use

- New Hampshire: Trails for People and Wildlife Initiative
- Outdoor Recreation and Elk: A Colorado Case Study
- Artificial light at night is a top predictor of bird migration stopover density
- Bird Migration Forecasting Dashboard
- Audubon Bird Migration Explorer and Lights Out Program
- USGS: Nonindigenous Aquatic Species resource
- USDA: National Invasive Species Information Center

Land and Water Management

- Sagebrush Conservation Design to Proactively Restore America's Sagebrush Biome
- Connectivity and invasive species management: towards an integrated landscape approach

Law, Policy, and Planning

- Teton County Land Development Regulations: Natural Resource Overlay Standards: Exterior lighting standards
- County of Ventura – Habitat Connectivity and Wildlife Corridor Ordinance: outdoor night-lighting regulation

Appendix 2. Examples of State Terrestrial Connectivity Mapping

Minnesota integrated cores and dispersal corridors from its Prairie Conservation Plan into its 2015 SWAP. The 2015 Minnesota SWAP also used a Watershed Health Assessment Framework to score aquatic, terrestrial, and riparian connectivity values across the state.
Delaware created the Delaware Ecological Network (DEN) to map priority wetland and terrestrial habitats. The DEN was used to inform Delaware's 215 SWAP and is composed of core areas, which contain high-quality habitats, existing corridors that link core areas together, and potential corridors. The DEN was developed in 2007 by researchers at Defenders of Wildlife

Vermont Fish and Wildlife used a State Wildlife Grant and worked with partners at Vermont Land Trust to develop its Vermont Conservation Design, which maps forest blocks and habitat connectors. Layers associated with the Conservation Design are available to the public through the Biofinder portal and are currently used to inform regulatory decisions related to renewable energy development and town planning.

Oregon formed a Habitat Connectivity Consortium in 2016 to promote landscape connectivity and mitigate barriers to wildlife movement. The collaborative Consortium, led by the Oregon Department of Fish and Wildlife, guided the creation of the Oregon Connectivity Assessment and Mapping Project, which mapped statewide connectivity for 54 species to highlight priority wildlife "Regions" for species movement and "connectors", which are optimal pathways between Regions. The project also contains primary and secondary conservation recommendations for each polygon.

The collaborative Washington Habitat Connectivity Workgroup was formed in 2007 and subsequently initiated the Washington Connected Landscape Project. They first analyzed connectivity at a statewide scale for a prioritized subset of focal species, and have developed ecoregional analyses, including transboundary connectivity that extends into British Columbia, to better inform site scale actions. Washington developed two publicly-available GIS tools to support regional wildlife habitat connectivity analyses- the Linkage Mapper, for wildlife habitat corridor mapping, and the HCA Toolkit, which identifies habitat concentration areas. These have been used by other states, such as New Jersey and New Hampshire.

California developed an interactive online mapping tool to enhance connectivity as part of the Essential Habitat Connectivity Project. The tool is intended to focus on large areas important to maintain ecological integrity at broad scales. The California Department of Transportation and the California Department of Fish and Game collaborated to develop the broad-scale connectivity prioritization product. Additionally, the state has a Fish Passage Advisory Committee to collaboratively share science and data related to fish barriers and to prioritize the most important locations for remediation and recovery of species.

In 2017, the New Hampshire Fish and Game Department, NH Department of Transportation, and NH Department of Environmental Services partnered to research wildlife corridors in response to requirements from Senate Bill 376. To develop the New Hampshire Wildlife Corridors map, areas of wildlife movement and dispersal were identified using the NH Wildlife Connectivity Model (revised 2020). Then, Linkage Mapper was used to map connections between core wildlife habitats. Finally, the corridors where wildlife is predicted to move most easily, especially riparian corridors, were identified.

To inform its 2015 SWAP, the Maryland Department of Natural Resources used land use cover maps, satellite and aerial imagery, and environmental and biological databases developed through the Natural Heritage Program, the Forest Service, and the Maryland Biological Stream Survey to identify and map a network of hubs and corridors. The hub and corridor system allowed MD DNR to identify areas where more corridors are needed, or where rare communities are isolated. The final map captured 2.4 million acres of private and public land in Maryland, and highlighted that less than 30% of the state's mapped green infrastructure was protected

For their 2015 SWAP, Rhode Island identified contiguous blocks of unfragmented forest greater than 250 acres ("core areas" in the plan) and connections between them. These were informed by The Nature Conservancy's regional connectivity analysis from the Northeast Terrestrial Resilience project, and natural corridors associated with river systems.

Florida has done extensive work identifying and prioritizing and network of core habitat and corridors. The Florida Ecological Greenways Network (FEGN) is a statewide database that identifies and prioritizes a functionally connected statewide ecological network of public and private conservation lands. The state has also identified "Critical Connections" as the narrow, irreplaceable connections in the Florida Wildlife Corridor with the highest ecological significance and the greatest urgency for conservation.

New Jersey's Connecting Habitat Across New Jersey (CHANJ) mapping project was initiated in 2012 at a meeting that convened over 40 agencies and programs to discuss the issue of fragmentation in the state. Staff then developed the CHANJ tool, which is an online interactive map and a guidance document for prioritizing land protection, management, and road barrier mitigation. The tool was referenced in the State Wildlife Action Plan and subsequently informed the implementation of 2016 Flood Hazard Area Control Act regulations that ensure wildlife considerations are integrated into transportation permitting for bridges and culverts.

Virginia recently developed a Wildlife Corridor Action Plan which emphasized protection of wildlife habitat corridors and reduction of wildlife-vehicle collisions. They used Conserve Virginia and

Virginia Natural Landscape Assessment conservation planning tools, as well as other data sources, to identify high-priority wildlife corridors and designated them as the state's Wildlife Biodiversity Resilience Corridors. To identify road segments experiencing high occurrences of wildlife-vehicle conflicts, a geospatial analysis was performed using a subset of data from two databases, Virginia Roads and Virginia Smart Roads.

In 2019, Idaho used a SWAP Enhancement grant to develop habitat connectivity models in collaboration with the Nature Conservancy. Using connectivity models, they chose a suite of SGCN and characterized landscape conditions, large intact blocks, connectivity zones, and overall terrestrial permeability. Their final maps depict regional connectivity within Idaho.