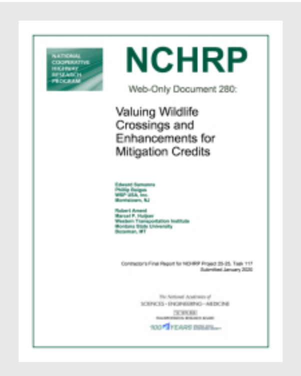
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Valuing Wildlife Crossings and Enhancements for Mitigation Credits

# Valuing Wildlife Crossings and Enhancements for Mitigation Credits (2020)

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# NCHRP

Web-Only Document 280:

# Valuing Wildlife Crossings and Enhancements for Mitigation Credits

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Contractor's Final Report for NCHRP Project 25-25, Task 117
Submitted January 2020

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C O O P E R A T I V E R E S E A R C H P R O G R A M S


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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AADT | average annual daily traffic |
| ALIVE | A Landscape-Level Inventory of Valued Ecosystem Components |
| Caltrans | California Department of Transportation |
| CDFW | California Department of Fish and Wildlife |
| CDOT | Colorado Departments of Transportation |
| CEQA | California Environmental Quality Act |
| CFR | Code of Federal Regulations |
| DOT | Department of Transportation |
| ESA | Endangered Species Act |
| FAST Act | Fixing America's Surface Transportation Act of 2015 |
| FDEP | Florida Department of Environmental Protection |
| FDOT | Florida DOT |
| FHWA | Federal Highway Administration |
| GIS | geographical information systems |
| GPS | global positioning system |
| HCP | habitat conservation plan |
| IEF | Integrated Ecological Framework |
| Laurel Curve Project | Laurel Curve Wildlife Habitat Connectivity Project |
| MAP-21 | Moving Ahead for Progress in the 21st Century Act of 2012 |
| MCA | mitigation credit agreement |
| NDOT | Nevada Department of Transportation |
| NEPA | National Environmental Policy Act |
| NCHRP | National Cooperative Highway Research Program |
| NGO | non-governmental organization |
| P.L. | Public Law |
| RCIS | Regional Conservation Investment Strategy |
| RIBITS | Regulatory In-lieu Fee and Bank Tracking System |
| SAFETEA-LU | Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users |
| SHOPP | State Highway Operation and Protection Program |
| SHRP 2 | second Strategic Highway Research Program |

| | |
|---|---|
| SR | State Road |
| UMAM | Uniform Mitigation Assessment Method |
| USACE | U.S. Army Corps of Engineers |
| USFWS | United States Fish and Wildlife Services |
| WCC | Wildlife Crossing Committee |
| WVCs | wildlife-vehicle collisions |

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## APPENDIX



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# EXECUTIVE SUMMARY

This report summarizes the activities conducted as part of National Cooperative Highway Research Program (NCHRP) 25-25, Task 117, *Valuing Wildlife Crossing and Enhancements for Mitigation Credits*. Mitigation crediting could provide a valuation approach that state DOTs could use to promote the construction of wildlife crossings and other enhancements to mitigate transportation project impacts. The two objectives of this research are to:

- Collect and synthesize current information on valuation methods, metrics, criteria for credit development, and crediting mechanisms used by state DOTs and their partners for calculating and applying mitigation and advance mitigation credits for wildlife connectivity improvements.
- Identify existing and potential quantitative methods and approaches for establishing the mitigation values of wildlife overpasses, underpasses, bridges, and culverts for habitat connectivity, and how that value is translated to mitigation credits.

Research activities included identifying relevant examples and current practices for valuing wildlife connectivity mitigation by performing an online survey of 234 state DOTs and natural resources agencies and conducting telephone interviews with 13 practitioners from four state DOTs. The literature review revealed few examples of metrics used in practice to value wildlife connectivity mitigation, so the online survey sought to identify the most-experienced practitioners for telephone interviews. Based on the findings from the interviews, four case studies of wildlife connectivity mitigation, from California, Colorado, and Florida, are presented.

The online survey revealed a consensus among state DOT and natural resources agency practitioners that dedicated wildlife crossings provide a direct benefit to wildlife of all sizes and a highway safety improvement to the public by reducing collisions with large animals. The survey results also showed that the development of crediting and valuation systems for wildlife crossings is in the early stages in a handful of states and the lack of regulatory requirements and processes requiring compensatory mitigation could be an impediment to developing a crediting approach. This research noted that an advance mitigation framework, as described in the Integrated Ecological Framework (NAS 2012), is an appropriate approach for state DOTs to follow when developing valuation metrics for wildlife connectivity mitigation crediting. California is the only state currently with a regulatory framework under which wildlife connectivity mitigation projects undertaken by a state DOT can establish mitigation credits.

The literature review revealed many potential metrics to value wildlife connectivity. Each one could be assigned into one of four categories: (1) *condition-based connectivity metrics*—types of measurements based on the physical, chemical, and biological attributes of a system, such the highway footprint area within the highway crossing zone used by focal species; (2) f*unction-based connectivity metrics*—types of measurements based on wildlife habitats and ecosystem processes, such as the number of individuals of focal species crossing the highway, or the habitat quality of connected or fragmented habitat; (3) *model-based connectivity metrics*—types of measurements based on computer models that combine elements of function- and condition-based metrics to estimate wildlife connectivity, such as species distribution models, animal movement models, and habitat-based population viability models; and (4) *avoided cost metrics*—types of measurements based on the economic value of wildlife or human life and/or property, such as reductions in insurance settlements due to wildlife-vehicle collisions (WVCs).

On a national level, identifying universal metrics or quantification methods for valuing wildlife connectivity mitigation appears to be infeasible, and practitioners agreed that metrics would most likely be ecosystem- and species-specific. Choosing appropriate metrics would depend on the life history and range(s) of the focal species and the availability of spatial data for focal species occurrences and WVCs. Also, under existing regulations, the use of credits for wildlife connectivity mitigation would most likely be focused on natural resource agency permit requirements that require state DOTs to compensate for impacts on threatened and endangered species.

Practitioners interviewed generally support using function-based metrics to value mitigation credits for wildlife crossings and other connectivity enhancements. However, to quantify pre-construction versus post-construction wildlife values, function-based metrics would require extensive biological data for focal species and ecosystems. Adequate data to accurately quantify values are only available for a limited number of species and locations. Even in cases where studies have documented wildlife movement in relation to highways, the lack of comprehensive data and other confounding factors could pose a difficulty to quantifying the ecological value of a wildlife crossing or other connectivity enhancement. In contrast, using condition-based metrics to value wildlife connectivity mitigation would be more straightforward; however, they would not explicitly measure the ecological gain from the mitigation. Similarly, model-based metrics would not directly measure the ecological gain from wildlife connectivity mitigation, but they have the advantage of being transparent and repeatable. Model-based metrics could also incorporate existing ecological datasets and results from prior modeling efforts to predict ecological gain for multiple species. Both condition- and model-based metrics would serve as a proxy for performance (i.e., implementing a wildlife connectivity mitigation measure is expected to achieve its intended benefit for focal species). Lastly, many state DOTs have used avoided cost metrics (i.e., reduced WVCs) in cost-benefit models to prioritize wildlife connectivity mitigation for animals large enough to damage vehicles based on the predicted improvement in motorist safety and wildlife conservation. Because most state DOTs have roadkill data-collection protocols in place and maintain databases of WVCs, for applicable species, this avoided cost metric could be among the most practical metrics to value wildlife connectivity mitigation credits.

In the absence of a market-driven mitigation banking program that guides credit costs (like the one that exists for wetland and stream mitigation bank credits), the economic impacts of WVCs could be an important metric to monetize the value of wildlife crossings or other connectivity mitigation measures. Also, State DOTs can quantify values that are intrinsic to wildlife using various non-market valuation techniques to calculate the value of animal populations that would be restored or maintained by a wildlife crossings or other connectivity enhancement, including revealed preference techniques, stated preference techniques, or techniques based on poaching fines and restitution.

Only the California Department of Transportation (Caltrans) and Florida Department of Transportation (FDOT) have generated mitigation credits for wildlife crossing projects. The approach taken by Caltrans for the Laurel Curve Wildlife Habitat Connectivity Project, as discussed in section 5.1, does not directly measure the ecological gain from the wildlife crossing; rather, credits are generated based on the highway footprint within the reach where connectivity would be improved. This straightforward condition-based metric assumes that, within the zone where wildlife connectivity would be improved, increasing permeability of a larger footprint would equate to greater benefits to focal species. The Laurel Curve Project is a proof-of-concept effort that demonstrates a framework for developing credit agreements for wildlife crossing structures, and how credits generated from a wildlife crossing could be applied as mitigation for future transportation projects. FDOT has valued wildlife connectivity mitigation using the habitat connectivity scores calculated by the Florida Department of Environmental Protection’s Uniform Mitigation Assessment Methodology, which expresses credits in terms of the functional gain generated from a proposed wildlife crossing structure. As detailed section 5.2, FDOT has used this standardized wetland assessment methodology for valuing wildlife connectivity mitigation on several highway projects but does not have a program that allows it to apply credits to other transportation projects.

# 1.0 INTRODUCTION

State DOTs and their regional and local partners are increasingly focused on wildlife connectivity because mounting evidence demonstrates the effectiveness of wildlife crossing structures (i.e., overpasses and underpasses) and other connectivity enhancements at improving motorist safety and conserving wildlife. Wildlife crossings and other connectivity enhancements can be cost-effective measures to facilitate animal movement across highways for numerous species and are necessary for the recovery of many threatened and endangered species. Many state DOTs are beginning to incorporate wildlife connectivity planning into their long-term transportation plans. Mitigation crediting may provide a valuation approach that state DOTs could employ to promote the construction of wildlife connectivity projects and mitigate certain transportation project impacts.

Evaluating current practices and emerging, innovative valuation approaches will provide state DOTs with information to more efficiently meet environmental permit requirements and develop successful mitigation measures, as well as help meet environmental stewardship goals and responsibilities. This study synthesizes current information about mitigation crediting practices used by state DOTs and their partners for calculating and applying mitigation credits for wildlife crossings and other connectivity enhancements that provide safe passage for wildlife across highways. It examines various facets of mitigation crediting for wildlife connectivity, focusing specifically on the valuation metrics and methods used for credit development and related findings for state DOTs to consider when developing a program for advance mitigation and crediting for wildlife connectivity.

The terms “credit,” “wildlife connectivity mitigation,” and “advance mitigation” are used throughout this report and are defined as follows:

- *Credit*—unit of exchange that serves as the currency for valuing biodiversity, ecosystem services, or an expected ecological outcome. In the context of this report, credit specifically references a measure of gain in wildlife connectivity functions through the restoration, enhancement, or protection of habitat connectivity by wildlife crossings and highway enhancements that increase permeability for focal species.
- *Wildlife connectivity mitigation*—any functional wildlife crossing structure (underpass or overpass), or other highway enhancements (e.g., retrofits of existing culverts, fencing, jump outs, or driver warning devices) used to mitigate the fragmentation effects of transportation projects to wildlife and habitat connectivity. In this report, this term is used synonymously with “wildlife crossing(s) and/or other connectivity enhancement(s).”
- *Advance mitigation*—a process in which credits generated from mitigation measures can be applied at a later date to mitigate unavoidable impacts of future transportation projects and to satisfy permit conditions. Funding for advance mitigation is provided early in the planning process to implement mitigation measures that generate credits that can be purchased by state DOTs to mitigate future transportation projects (Sciara et al. 2015a). By considering mitigation development early in the planning process, there is an opportunity to better align mitigation with regional conservation priorities, including wildlife connectivity.

The impetus for a state to establish an advance mitigation/crediting program that includes wildlife connectivity credit establishment is based on the opportunity to provide additional, effective wildlife connectivity than is required to mitigate for adverse impacts as part of a transportation project as well as help address the need for added flexibility in addressing the legacy wildlife connectivity impacts and motorist safety impacts of the roadway itself.

# 2.0 SUMMARY OF LITERATURE REVIEW, SURVEY, AND PRACTITIONER INTERVIEW FINDINGS

## 2.1 LITERATURE REVIEW

### 2.1.1 Legal, Planning, and Policy Considerations

To comply with federal National Environmental Policy Act (NEPA), Endangered Species Act (ESA), and Clean Water Act approvals and permits, as well as state regulatory approvals and permits, transportation projects that affect wildlife connectivity may be required to provide mitigation for maintaining safe passage of wildlife. A consideration of applicable federal laws for protecting wildlife is necessary to understand wildlife connectivity mitigation for transportation projects. The Federal Highway Administration (FHWA) website (https://www.fhwa.dot.gov/environment/env_sum.cfm) gives a thorough review of federal wildlife legislation affecting transportation infrastructure in the United States. Additional detail about wildlife-related legislation applicable to transportation projects can be found in Table 1 of the California Department of Transportation (Caltrans) *Wildlife Crossings Guidance Manual* (Caltrans 2009).

**National Environmental Policy Act Planning**

NEPA applies to all federally funded actions, including federally funded and approved state DOT actions. Under NEPA, state DOTs must analyze environmental impacts of transportation projects, including reduced wildlife connectivity, with a systematic, interdisciplinary approach. Projects that would decrease wildlife connectivity or increase WVCs could be considered an adverse environmental effect, which under NEPA, could require state DOTs to provide mitigation in the form of wildlife crossings or other connectivity enhancements to reduce the adverse effect of the project. The NEPA planning process can serve to bring stakeholders and scientific expertise together to identify effective wildlife connectivity mitigation options for a highway project (see section 5.3 and 5.4), providing state DOTs an opportunity to consider wildlife connectivity mitigation early in the planning and funding process.

**Endangered Species Act Compliance**

The requirement for wildlife connectivity mitigation is sometimes a result of the potential "incidental taking" of species listed under the ESA. If a transportation project would impede the movement of a threatened or endangered species and adversely affect individuals, then the U.S. Fish and Wildlife Service (USFWS) could require state DOTs to implement wildlife connectivity mitigation measures (Caltrans 2009). State DOTs may choose to implement either permittee-responsible mitigation, an in-lieu fee program (where available), or purchase credits via a USFWS-approved conservation bank (USDOI 2013).

As of 2008, Huijser et al. (2008a, 2008b) listed 21 federally listed threatened or endangered species in the United States for which road mortality is among the major threats to their survival, including:

- Mammals: Lower Keys marsh rabbit (*Sylvilagus palustris hefner*) in Florida; Key deer (*Odocoileus virginianus clavium*) in Florida; desert bighorn sheep (*Ovis canadensis nelsoni*) in peninsular California; San Joaquin kit fox (*Vulpes macrotis*) in California; Canada lynx (*Lynx canadensis*) in Colorado, Oregon, Montana, Minnesota, and Idaho; ocelot (*Leopardus pardalis*) in Texas; Florida panther (*Puma concolor coryi*) in Florida; and red wolf (*Canus lupus rufus*) in North Carolina
- Reptiles: American crocodile (*Crocodylus acutus*) in Florida; desert tortoise (*Gopherus agassizii* and *Gopherus morafkai*) in Arizona, California, and Nevada; gopher tortoise (*Gopherus polyphemus*) in Alabama; Alabama red-bellied turtle (*Pseudemys alabamensis*) in Alabama and

Mississippi; bog turtle (*Glyptemys muhlenbergii*) in New Jersey, New York, North Carolina, and Pennsylvania; copperbelly water snake (*Nerodia erythrogaster neglecta*) in Indiana, Michigan, and Ohio; and eastern indigo snake (*Drymarchon couperi*) in Alabama, Florida, and Georgia

- Amphibians: California tiger salamander (*Ambystoma californiense*) in California; reticulated flatwoods salamander (*Ambystoma bishopi*) in Alabama and Georgia; and Houston toad (*Bufo houstonensis*) in Texas
- Birds: Audubon's crested caracara (*Polyborus plancus audubonii*) in Florida; Hawaiian goose (*Branta sandvicensis*) in Hawaii; and Florida scrub-jay (*Aphelocoma coerulescens*) in Florida

Bissonette et al. (2008a) identified additional threatened and endangered species that are targets for wildlife crossings, including the grizzly bear (*Ursus arctos*) in Montana; Preble's jumping mouse (*Zapus hudsonius preblei*) in Colorado; arroyo toad (*Anaxyrus californicus*) in California; pygmy owl (*Glaucidium brasilianum cactorum*) in Arizona; Blanding's turtle (*Emydoidea blandingii*) in Minnesota; and diamondback terrapin (*Malaclemys terrapin*) in Delaware and Georgia.

Buying conservation bank credits is an option to mitigate unavoidable impacts of transportation projects on federally listed species when on-site avoidance, minimization, or compensation measures are not available. Conservation banking has grown exponentially in recent years. As 2013, conservation banks were available for 35 different species (USDOI 2013). Poudel (2017) reported that there were 137 conservation banks in the United States, generating mitigation credits through the conservation of approximately 160,000 acres of land for species listed under the ESA. Nearly 95% of the habitat protected by conservation banks is in the State of California, although considerable growth has recently occurred in Oregon, Texas, Florida, and North Carolina (Pindilli and Casey 2015). Information on these banks can be found at the Regulatory In-lieu Fee and Bank Tracking System (RIBITS), maintained by the U.S. Army Corps of Engineers (USACE), online at https://ribits.usace.army.mil.

Despite the need for wildlife crossings or other connectivity enhancements to mitigate impacts of transportation projects on federally listed species, no conservation banks have established or currently hold credits generated from wildlife connectivity mitigation. To date, it appears that the only federally listed species for which USFWS has calculated mitigation credit requirements based on impacts to wildlife connectivity from a transportation project is the Florida panther (see section 5.2).

**Habitat Conservation Plans**

Under the authority of the ESA, state DOTs mitigate for impacts to federally listed species by developing HCPs (see USFWS 2011). HCPs are science-based, multispecies plans developed to offset incidental take. HCPs must accompany an application for an incidental take permit. In a sense, HCPs are a type of advance mitigation, whereby a future project's "covered activities" are permitted for "take." Mitigation measures vary among HCPs, but most incorporate offsite mitigation whereby the agency administering the HCP acquires protected land to mitigate the effects of development activities. HCPs are said to promote more effective preservation of high-value habitat sites, including those that provide habitat connectivity (Wilkinson et al. 2009).

State DOTs increasingly use HCPs to protect federally listed species in regional transportation planning, especially for the species noted above where roadways are a demonstrated extinction risk. There is a trend toward regional-scale HCPs, or specifically toward multispecies HCPs (Lederman 2017, Lederman and Wachs 2016). Examples of regional HCPs for transportation projects that could affect federally listed species include the Balcones Canyonlands Conservation Plan, which covers Texas DOT's impacts on eight federally listed species, including the endangered golden-cheeked warbler (*Setophaga chrysoparia*) and the delisted black-capped vireo (*Vireo atricapilla*) (City of Austin and Travis County 1996); the

Western Riverside County Multiple Species Habitat Conservation Plan, which covers Caltrans' impacts on 146 covered state-listed, federally listed, and other special-status species (Riverside County Transportation and Land Management Agency 2003); and the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan, which covers Caltrans' impacts on 97 covered state-listed, federally listed, and other special-status species (San Joaquin Council of Governments 2000). Thus, an increasing number of transportation projects will likely need to consider development of an HCP to meet mitigation requirements under the ESA. It is reasonably foreseeable that acceptable mitigation measures for many federally listed species could include wildlife connectivity mitigation.

### Compensatory Mitigation Under the Clean Water Act

Under the authority of the Clean Water Act, USACE may require compensatory mitigation for actions affecting streams, wetlands, and other waters of the United States. Section 404 prescribes allowances for compensatory mitigation for unavoidable losses of aquatic resources, which may include the purchase of mitigation credits. Although the purpose of the Clean Water Act is to maintain clean water, many transportation projects involve modifications to existing drainage structures (i.e., bridges and culverts) that require Clean Water Act approval; thus, opportunities exist to incorporate safe passage for wildlife. In addition, a disproportionate number of federally listed species use wetland and stream habitats, providing state DOTs with an additional impetus to explore options for wildlife connectivity mitigation at existing drainage structures to generate wetland mitigation credits based on metrics that quantify the ecological linkages provided by wetlands and floodplains (see section 5.3). As of 1991, wetland habitats fully supported 60% of all threatened species and 40% of all endangered species (Flynn 1996). Wildlife connectivity mitigation is thus often required where highways cross streams and wetlands, and opportunities often exist to enhance wildlife connectivity at highway bridges and culverts. For example, bridges can be extended beyond their stream widths to provide for terrestrial wildlife movement along riparian corridors (Clevenger and Waltho 2000), and wildlife shelving along culverts can facilitate passage by terrestrial small-medium vertebrates (Foresman 2001).

### The Ecological Approach to Transportation Planning and the Integrated Ecological Framework

In 2006, FHWA, the U.S. Bureau of Land Management, the U.S. Environmental Protection Agency, National Marine Fisheries Service, the National Park Service, USACE, the U.S. Department of Agriculture, Forest Service, and USFWS, along with several state DOTs, and others published *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* (Brown 2006), in which FHWA and its federal partners presented their commitment to using an ecosystem approach to infrastructure project mitigation via advance mitigation. Generating advance credits for wildlife connectivity mitigation would provide policy options and tools to conserve wildlife corridors and sensitive species, which would align with federal and state directives for maintaining or enhancing wildlife movement at a regional scale (e.g., Western Governors' Association 2008, Governor's Office of Planning and Research 2018).

Developing a crediting system for transportation project impacts is identified as a key step in the ecological approach to integrate transportation and conservation planning (see Brown 2006). This advance mitigation approach was further developed and presented as the Integrated Ecological Framework (IEF) that the Transportation Research Board prepared as part of the second Strategic Highway Research Program (SHRP 2) (NAS 2012, 2013). The IEF would provide a useful approach for implementing wildlife connectivity projects via mitigation credits under an Advance Mitigation Program, which would address many of the predictable adverse impacts on wildlife that result from future transportation projects. The focus of this study aligns with step 6 of the IEF, which relates to developing "a consistent strategy and metrics to measure ecological impacts, restoration benefits, and long-term performance" (NAS 2012). After project-specific avoidance and minimization measures are taken, unavoidable impacts could be mitigated by applying credits from in-kind or other out-of-kind wildlife connectivity mitigation.

An advance mitigation crediting strategy to value wildlife connectivity would require a move away from a piecemeal, project-by-project wildlife connectivity mitigation approach toward a coordinated, statewide or regional approach. Regional conservation plans (e.g., Regional Conservation Investment Strategies [RCIS] in California) or regional permits (e.g., regional HCPs) incorporate a high level of specificity about the predicted impacts of planned transportation projects to identify an appropriate level of wildlife mitigation. The use of such plans could facilitate more effective mitigation by providing an early assessment of regional mitigation needs of future landscape-level impacts from multiple infrastructure projects, which would be more efficient than traditional project-by-project mitigation (Beatley 1992, Lederman and Wachs 2014, 2016). Furthermore, providing wildlife mitigation that could be applied to multiple transportation projects on a larger geographic scale could contribute to landscape connectivity at identified habitat corridors and facilitate species' movement via wildlife crossings or other connectivity enhancements.

**Programmatic Mitigation Plans**

State DOTs have long planning horizons, and FHWA allows state DOTs to develop a mitigation framework as part of their planning process to address future impacts of transportation projects (see 23 Code of Federal Regulations [CFR] 450.214 – Development and content of the long-range statewide transportation plan, and 23 CFR 450.320 – Development of programmatic mitigation plan). These "programmatic mitigation plans" can be developed at local, regional, or statewide scales for an ecosystem, watershed, or species. The plans can encompass multiple environmental resources, including wildlife habitat and can be integrated with other plans that prioritize wildlife crossings, such as statewide connectivity assessments/strategies, state wildlife action plans, species recovery plans, growth management plans, or land use plans.

Although federal laws and regulations pertaining to federal highways, including national highway safety, do not specify the adherence to a specific planning framework, the FHWA'S Planning and Environmental Linkages (PEL) program encourages "a more seamless decision-making process that minimizes duplication of effort, promotes environmental stewardship, and streamlines project delivery" (Breck et al. 2015). To that aim, Brown (2006) and IEF provide guidance to incorporate advance mitigation into the transportation planning process. The planning and environmental linkage planning process was recently amended to reflect FHWA's January 2018 Working Agreement with the U.S. Coast Guard, USACE, the U.S. Environmental Protection Agency, USFWS, and the National Marine Fisheries Services to implement Executive Order 13807: Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure issued on August 15, 2017, (see https://www.environment.fhwa.dot.gov/nepa/oneFederal_decision.aspx), also known as One Federal Decision. The purpose of the agreement is to accelerate and coordinate the planning, environmental review, permitting, and decision-making for FHWA major infrastructure projects and support the intent of the executive order.

Generating credits for wildlife connectivity mitigation measures would be most effective under an advance mitigation framework for many reasons. First, wildlife connectivity mitigation seeks to restore habitat connectivity and benefit populations across a regional landscape, so its implementation requires an extensive analysis of the various environmental and human factors contributing to wildlife movement. This analysis requires an understanding of future traffic patterns and land development with respect to focal species' movement patterns, population stability, and genetic diversity (e.g., Ament et al. 2014).

Such analyses of wildlife connectivity, as well as future human transportation requirements, are a requisite step of advance mitigation programs.

Advance mitigation programs have been more effective at creating better environmental protection and alleviating transportation problems than performing mitigation for transportation projects on a project-by-project basis (Greer and Som 2010). Sciara et al. (2017) assessed the evidence for cost savings realized through advance mitigation from avoided upfront costs and reduced transportation project delay and found that most practitioners of advance mitigation reported cost savings. They estimate that advance mitigation could reduce project delays related to environmental review by 1.3 to 5 months per project. Costs savings described by Sciara et al. (2017) that would apply to wildlife connectivity mitigation include reduced costs as a result of greater flexibility in project scheduling; expedited project approvals and lack of procedural delays; and cheaper land acquisition or construction materials before price escalation. Furthermore, Sciara et al. (2017) argue that advance mitigation could minimize legal costs by reducing the likelihood of legal challenges for environmental reasons. Lastly, advance mitigation is a proper framework for crediting wildlife connectivity mitigation because agency priorities and transportation project schedules are often misaligned, such that mitigation opportunities are missed (ARC Solutions 2017). For example, most wildlife connectivity mitigation is implemented after being identified during transportation project planning, and funding is then pursued from various sources, which may or may not be available on the same schedule as the transportation project. Advance mitigation could serve to address this planning and funding disconnect. Furthermore, many wildlife connectivity mitigation projects could yield outstanding ecological benefits, but a delay in their implementation could potentially lead to a permanent loss of the opportunity. Because of increasing development in many places with high-value wildlife resources, these circumstances are becoming more common (Brown 2006), and advance mitigation could serve to better address such opportunities.

State DOTs, working with federal and state partners, could use the IEF as a blueprint to guide their development of consistent valuation and crediting methods (see table ES.1 of NAS 2012). Once a consistent strategy and metrics are identified to quantify the adverse effects of a transportation project on wildlife connectivity, or the restoration benefits of a wildlife connectivity mitigation measure, the subsequent steps are to “carry out innovative, ecosystem-based crediting strategies, interagency agreements, mitigation plans, programmatic consultations, and permitting” (NAS 2013).

### Highway Funding and Authorization Acts

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU; Public Law [P.L.] 109-59) of 2005 contains several sections that address improving wildlife connectivity and reducing WVCs. Under SAFEATEA-LU, the Transportation Enhancements Program helps fund environmental mitigation and includes a provision for reducing vehicle-caused wildlife mortality while maintaining habitat connectivity (Section 101(a)(35) of Title 23 United States Code). Section 6001 also requires early consultation among state DOTs and natural resources agencies and tribes and consideration of applicable plans (e.g., federally listed species recovery plans, state wildlife action plans). Early consultation provides more opportunities for state DOTs to consider wildlife mitigation strategies, including discussions about wildlife connectivity mitigation, early in the transportation planning process. Consultation is required to involve a “discussion of potential environmental mitigation activities and potential areas to carry out these activities, including activities that may have the greatest potential to restore and maintain the environmental functions affected by the plan.” This and other provisions of the SAFETEA-LU that allow for funding of wildlife connectivity mitigation, such as the Transportation Alternatives Program (National Transportation Alternatives Clearinghouse 2012, FHWA 2014), have since been canceled or superseded by subsequent FHWA funding authorizations. These include the Moving Ahead for Progress in the 21st Century Act of 2012 (MAP-21; P.L. 112-141) and the

Fixing America's Surface Transportation Act of 2015 (FAST Act; P.L. 114-94). Ament and Callahan (2019) provide a summary of six key federal transportation programs that allow their funds to be expended on wildlife mitigation from MAP-21 and the FAST Act.

**Wildlife Connectivity Mitigation Costs**

Effective wildlife connectivity mitigation along highways can be expensive. Recently constructed structures in Colorado cost about $300,000 to $1,475,000, with associated fencing costing approximately $98,900 per lane mile (Kintsch et al. 2019). State DOTs do not generally have dedicated funding for wildlife connectivity mitigation, so mitigation often competes with other highway assets for program funding. Wildlife connectivity mitigation measures are usually constructed based on opportunity, either to mitigate for a proposed transportation project or where strong public interest exists for conserving economically valuable species like big game (Smith 2019). To implement wildlife connectivity mitigation, multi-stakeholder partnerships are often necessary to leverage funding. The Nevada Department of Transportation (NDOT) provides an overview of funding resources for wildlife connectivity mitigation in chapter 7 of its *Prioritization of Wildlife-Vehicle Conflict in Nevada*, including the available federal programs and other potential funding from local governments, non-profit organizations, and citizen initiatives (Cramer and McGinty 2018).

### 2.1.2 Potential Valuation Metrics for Wildlife Connectivity Mitigation Credits

Mitigation credits are typically based on units of measure that can be quantified (e.g., an acre of land) and monetized (e.g., the dollar value of that land) (Kagan et al. 2014). According to Pindilli and Casey (2015), "credits [at conservation banks] represent the biodiversity benefits that conservation banks yield." Determining the number of credits for a wildlife mitigation measure is typically a function of habitat area, habitat condition, location, and/or focal species and includes species counts, population abundance, and/or breeding pair observations (Pindilli and Casey 2015). USFWS (2012a) states that "a credit may be equivalent to: (1) an acre of habitat for a particular species; (2) the amount of habitat required to support a breeding pair; (3) a wetland unit along with its supporting uplands; or (4) some other measure of habitat or its value to the listed species."

No common metrics are used in the United States to measure the mitigation value of wildlife crossings and other connectivity enhancements; nor are there standard methods to calculate the number of credits that could be generated from these types of mitigation. Only a handful of wildlife connectivity mitigation projects to date have generated mitigation credits, and only one project in California has generated credits for a stand-alone wildlife crossing. An extensive body of research provides potential metrics that could be used to either quantify the conservation value of wildlife connectivity mitigation to focal species and the resulting number of mitigation credits or quantify the impacts of future transportation projects to wildlife connectivity and the resulting number of mitigation credits that a state DOT could purchase to mitigate an unavoidable impact. These topics are explored further below and in section 5.0.

The published literature reveals that wildlife connectivity mitigation aims to conserve wildlife and reduce WVCs, so mitigation credits could quantify the benefits to humans and wildlife. The metrics potentially useful for calculating credits for wildlife connectivity mitigation measures fall into four categories: (1) condition-based connectivity metrics, (2) function-based connectivity metrics, (3) model-based connectivity metrics, and (4) avoided cost metrics.

**Condition-Based Connectivity Metrics**

Condition-based metrics are based on the physical, chemical, and biological attributes of a system (NAS 2012). For wildlife connectivity mitigation, condition-based metrics would likely quantify the physical attributes of a highway. Caltrans and the California Department of Fish and Wildlife (CDFW) calculated the number of credits based on an existing highway footprint for the Laurel Curve Wildlife Habitat Connectivity Project (Laurel Curve Project) on Highway 17 in Santa Cruz County (see section 5.1) (Caltrans and CDFW 2017). This is the only wildlife crossing structure that has generated wildlife connectivity mitigation credits in the United States. Although this quantification method is straightforward and equates to a common conservation bank accounting metric based on an area of habitat, it does not actually account for the ecological gain from the mitigation; however, the crossing's placement itself was based on years of research. The metric assumes that, within the zone where wildlife connectivity would be improved, increasing permeability of a larger footprint would equate to greater benefits to focal species, which may not necessarily be true.

Other possible condition-based attributes that could be factored into the value of a wildlife crossing or other connectivity mitigation measure include the number of existing drainage structures not designed for wildlife (e.g., bridges and culverts) but that potentially provide safe wildlife passage, the presence of potential barriers (e.g., fences and jersey barriers), and the extent of adjacent natural plant communities. Incorporating these attributes into the valuation would be plausible in cases where extensive information about a focal species' highway crossing behavior and its use or lack of use of existing structures exists (Servheen and Shoemaker 2003) or in cases where these behaviors can be systematically assessed (Kintsch and Cramer 2011). Although condition-based metrics like these do not explicitly quantify ecological gain, they would be calculated based on a putative increase in connectivity due to changes in various highway attributes.

Several road characteristics could be considered when evaluating the adverse impacts on wildlife connectivity from future transportation projects. The proportion of successful highway crossings by wildlife likely declines with increasing road size (number of lanes), traffic volume, and vehicle speeds. The number of WVCs likely increases with road size, traffic volume, and average speed (Clevenger and Waltho 2000). Therefore, direct impacts could be measured based on the increased area of impervious surface or the area of degraded wildlife habitat at locations where a highway creates a barrier to wildlife movement or prevents natural migrations (Booz-Allen & Hamilton, Inc. 1999). Metrics to quantify indirect impacts could include the area of natural habitat lost to future development as a result of a transportation project, based on land use transport modeling (NAS 2016). The condition-based metrics affecting large species could include traffic volume, speed limit, and type of median. For small focal species, other highway characteristics could include traffic volume, lane width, and median characteristics (Ernest and Sutherland 2017).

Traffic volume, typically measured by average annual daily traffic (AADT) and road width, are commonly cited as the major factors inhibiting road crossings (Beringer et al. 1990, Lovallo and Anderson 1996, Riley et al. 2006, Jacobson et al. 2016). Because traffic volume has a substantial influence on wildlife crossing behavior and is typically correlated with highway attributes such as lane width and number of lanes, some researchers have used AADT as a surrogate for other condition-based measurements of highway permeability (Jaeger et al. 2005, Charry and Jones 2009). Thus, traffic volume and projected increases in AADT could be used to quantify the number of credits needed to mitigate unavoidable transportation project impacts. However, the range of AADT values estimated for the point at which the highway becomes a barrier to various species is wide (Jacobson et al. 2016). Species-specific data would be necessary if traffic volume were used as a metric to quantify mitigation requirements for a transportation project. A study of collared grizzly bears around U.S. Highway 2 along the southern border of Glacier National Park indicated that traffic volume could be measured to evaluate wildlife connectivity for bears; when the highway exceeded 100 vehicles per hour, the road became a barrier to bear crossings (Waller and Servheen 2005). Measurements of traffic volumes 10 years later indicated fewer hours per day were available for grizzly bears to safely cross the road (Waller and Miller 2015). In the same region of Montana, Ament et al. (2014) combined traffic demand forecasting models with wildlife connectivity models to predict the crossing locations where mitigation would be necessary for grizzly bears in the future. By forecasting the impacts of increased human development on traffic, state DOTs could plan to mitigate predictable impacts on wildlife long before they occur, which would be cost-effective because it would focus limited resources where they would most benefit wildlife connectivity. Furthermore, such efforts to predict future wildlife connectivity mitigation needs would align with the framework of an Advance Mitigation Program, whereby wildlife crossings and other connectivity enhancements could be prioritized based on predicted impacts of a regional or statewide transportation plans.

**Function-Based Connectivity Metrics**

Function-based metrics would focus on habitats, structures, and processes as the basis for measuring wildlife connectivity (NAS 2012). Such metrics could value the ecological gain to focal species from wildlife connectivity mitigation by quantifying rates of movement of these species to accurately describe observed population dynamics (Kadoya 2009). The most robust and scientifically defensible valuation would require empirical biological data for all identified focal species on a road-by-road basis to identify the most cost-effective wildlife connectivity mitigation because species have specific preferences of crossing structures (Clevenger and Waltho 2000). For focal species that are easily monitored and highly valued by society, such as big game or large carnivores, it may be reasonable to calculate a single metric in a particular landscape. For example, using camera traps, Andis et al. (2017) measured wildlife movement of four large mammal species near a highway and compared it with wildlife movement through 15 adjacent underpasses to determine the effectiveness of the crossings. For a greater diversity of focal species or because of a lack of information, several function-based metrics could be combined that relate to the species' population abundance, demography, movement, habitat quantity and quality, or/and genetic diversity.

To calculate the ecological improvement attributable to wildlife connectivity mitigation, data are needed to quantify the degree to which the mitigation measure(s) enhance the population viability of focal species. Methods have been developed to accurately monitor the number of individuals, sex, and genetics of many taxa using wildlife crossings via remote cameras, track pads, radio telemetry, and noninvasive genetic sampling (e.g., hair snares). For rare species such as large carnivores, noninvasive genetic sampling has been effective at quantifying the increase in habitat connectivity provided by wildlife crossing structures used by black bears (*Ursus americanus;* Dixon et al. 2006), grizzly bears (Clevenger and Sawaya 2009), and wolverines (*Gulo gulo*; Sawaya et al. 2019). Such monitoring (e.g., via hair sampling) could quantify both the number of animals using a wildlife connectivity mitigation measure and the demography and population viability of focal species' populations before and after implementing a wildlife crossing or other connectivity enhancement.

Potential function-based metrics for calculating mitigation credits for wildlife connectivity projects could include the area of reconnected or fragmented habitat of focal species. This metric could be quantified as the habitat area that a focal species gains access to from the construction of a wildlife connectivity mitigation measure. In Oregon, the Willamette Partnership's Ecosystem Credit Accounting System includes several credit calculators that consider the context and connectivity of a mitigation site (Willamette Partnership 2013). For example, the credit calculator for upland prairie sites gives more weight to sites that are closer to other large prairie patches and have natural vegetation along the path between the site and the closest other prairie patch. Also, as part of the Willamette Partnership, Oregon DOT, in partnership with the Oregon Department of Fish and Wildlife and The Nature Conservancy, is piloting a fish passage banking system. A fish passage credit calculator quantifies the beneficial impacts on native migratory fish habitat from a restoration project that provides fish passage at existing barriers. The calculator takes information about the miles of potential fish use above the barrier, the quality of instream conditions, the riparian cover along the stream banks, and its interaction with the floodplain to calculate an overall score of habitat quality. That score is then multiplied by the habitat quantity (stream or watershed acres) to calculate credits or debits (Willamette Partnership 2017). The pilot project will test and evaluate the approach, conduct some credit bank projects, and determine if a fish passage credit bank could be applicable statewide (Oregon Department of Fish and Wildlife 2015).

A similar although less straightforward approach could be used to quantify credits for well-studied terrestrial species, such as big game populations with known seasonal ranges connected by migration routes that intersect highways. For example, it would have been possible to quantify the acres of winter- and summer-range habitat for pronghorn (*Antilocapa americana*) that was maintained as accessible by constructing an overpass in Wyoming (see Sawyer et al. 2016). For credit generation, empirical evidence would be required to demonstrate the effectiveness of the proposed mitigation for the focal species because there are species-specific preferences of crossing structures (Clevenger and Waltho 2000). Gender would also be important to monitor because crossing preferences can vary by sex (e.g., family groups of bears [females with cubs]) choosing overpasses over underpasses (Ford et al. 2017) or wolverine passage across a high-volume highway (Sawaya et al. 2019). Thus, the objectives of the crossing are important to consider for function-based metrics because male movement across a wildlife crossing structure would suggest that genetic connectivity is maintained or restored, but demographic effects could still occur if female movement is limited.

Other possible metrics analogous to the habitat quality assessment of the fish passage credit calculator could include wildlife crossing prioritization metrics used by Huijser et al. (2009), such as land use security, because locating wildlife crossings between tracts of intact, protected lands with connectivity to other protected lands is more likely to recover species (USDOI 2013). For example, the USFWS (2001) method for determining mitigation credits for the California red-legged frog (*Rana draytonii*) calculates more credits for parcels of land that facilitate habitat connectivity by assigning points for the “connectivity” subcategory of the “Importance to Recovery” criteria category. A 0.5-point credit is generated for the subcategory “connectivity” for any project that provides, or contribute significantly to, connectivity between: (1) separate populations of frogs; (2) separate core areas; and/or (3) separate critical habitat. Thus, in theory, wildlife crossings that connect large blocks of intact habitat, especially those protected from development, would generate more mitigation credits because greater numbers of species and individual animals would potentially benefit.

Credits based on function-based metrics should reflect the desired ecological outcome of a wildlife connectivity mitigation measure. An ecosystem approach defined by Brown (2006) involves the development of performance goals and outcomes for wildlife mitigation projects. Table 1 presents several performance goals and outcomes suggested by Brown (2006) that relate to wildlife connectivity mitigation that could serve as potential function-based metrics to value wildlife connectivity mitigation.

**Table 1. Possible performance goals and outcomes that could be used to value wildlife connectivity mitigation[a]**

| Possible Performance Goal | Possible Outcomes |
|---|---|
| Sustain Population Ecology | Maintained or increased population size and density |
| | Balanced population sex and age structure |
| | Reduced mortality and sustained viability |
| | Maintained or increased population growth |
| Maintain Species Distribution and Abundance | Sustained direct and indirect presence |
| Preserve Prevalence of Indicator Species | Increased population size |

| Possible Performance Goal | Possible Outcomes |
|---|---|
| | Long-term wildlife crossing use |
| Maintain Number of Species with Improved Population Status | Species counts |
| Maintain Fish and Wildlife Connectivity | Removal of X linear feet of barriers |
| | Improved habitat suitability index scores |
| | Maintained or increased of X acres or miles of adjacent habitat areas |
| | Improved access to X acres or miles of critical foraging areas |
| Reduce WVCs | Reduced number of WVCs |
| | Minimized maintenance costs (i.e., carcass collection) |
| Improved Recreation | Increased wildlife populations for viewing, hunting, and other activities (calculated based on state's market value of individual big game) |

[a] The listed performance goals and outcomes are adapted from Brown (2006) to include only those related to wildlife habitat connectivity.

The metrics used to identify potential wildlife crossings or “landscape linkages” could also be suitable to identify function-based metrics for valuing wildlife connectivity mitigation credits. Beier et al. (2005) developed a wildlife connectivity prioritization method that has been adopted by many practitioners to identify a set of 16 landscape linkages in southern California. The *Arizona Wildlife Linkage Assessment* (Nordhaugen et al. 2006) followed this multi-stakeholder, collaborative approach and evaluated statewide landscape connectivity in two dimensions: biological value, and threat and opportunity. Linkages with high rankings in both dimensions are the highest priority areas for accommodating continued movement of selected focal species and where wildlife crossings or other connectivity enhancements are most needed. To quantify biological value, the following criteria are typically the most important for identifying landscape linkages: (1) the size of wildlands connected, (2) the habitat quality of the smaller connected wildland, (3) the restoration potential of the linkage area, and (4) the occurrence of threatened and endangered or other special-status species (Beier et al. 2007). Although standard methods to enumerate credits based on these criteria do not exist, they could be effective metrics for valuing wildlife connectivity mitigation credits.

Similarly, Smith (1999) identified and prioritized “ecological interface zones” along highways in Florida by asking practitioners to rank various criteria used to prioritize locations of wildlife underpasses. He identified 11 criteria, ranked as follows:

1. Chronic roadkill sites
2. Known migration/movement routes
3. Identified hot spots of focal species
4. Landscape linkages (designated greenways)
5. Presence of listed species
6. Identified strategic habitat conservation areas

7. Riparian corridors (with potential for retrofitting existing structures)
8. Core conservation areas
9. Presence of separated required ecological resources (e.g., a forest patch and ephemeral wetland breeding area for amphibians that is separated by a highway) for a species or set of species
10. Public ownership (or in public land acquisition program) versus private lands
11. Potential to be included in proposed road improvement project

One or more of the above metrics described by Smith (1999) could be used to define a metric for valuing wildlife connectivity mitigation credits, which would, in effect, combine several factors to measure the ecological gain from a highway crossing or other connectivity enhancement.

Similarly, four of five metrics developed by Huijser et al. (2009) to identify potential sites for wildlife crossings and other connectivity enhancements could be incorporated into the value of mitigation credits. These include:

1. Local Conservation Value—the value of the highway mitigation to local wildlife conservation regardless of regional significance
2. Highway Mortality—relative rate of WVCs as a proxy for motorist safety risk
3. Land Use Security—the degree to which lands adjacent to the site are secured de facto for conservation
4. Regional Conservation Significance—the potential significance of highway mitigation to address wildlife conservation concerns of regional significance

The average score of the criteria was used to determine the relative importance for mitigation efforts among sites. Huijser et al. (2011) added a sixth category, species observations alongside the highway, to prioritize locations where wildlife crossings would be most effective in Jackson Hole, Wyoming. Criteria such as these could be incorporated into the calculation of mitigation credits as modifiers to the overall credit generation.

Clevenger (2005) and Clevenger and Huijser (2011) discuss the guiding principles for planning and measuring performance of wildlife connectivity mitigation that should be considered when developing function-based metrics for wildlife connectivity mitigation. These principles include (1) reducing mortality and facilitating movement within populations and genetic interchange; (2) ensuring that the biological requirements of finding food, cover, and mates are met (including migration); (3) facilitating dispersal from maternal ranges and recolonization after long absences; (4) facilitating populations to move in response to environmental changes and natural disasters; and (5) providing long-term maintenance of metapopulations, community stability, and ecosystem processes. Because of the wide variation in species' life histories and movement, any function-based metric aimed at enumerating these objectives would be species-specific and would depend on both the behavior of the focal species and the landscape structure (Wade et al. 2015). Therefore, Clevenger (2005) recommends using a hierarchical approach to identify function-based metrics for valuing wildlife connectivity mitigation, whereby the conservation value of wildlife crossings are evaluated at three "levels of connectivity:" (1) genetic connectivity—wildlife movement within populations via genetic interchange, which could be documented by predominantly adult male movement across road barriers; (2) demographic connectivity—genetic connectivity among populations, which could be documented by confirmed adult female movement across road barriers; and (3) functional connectivity—genetic and demographic connectivity among populations, including dispersal from maternal ranges, movement in response to environmental change and disturbance, and the long-term maintenance of metapopulations and ecosystem processes, which could be documented by confirmed dispersal of young females that survive and reproduce.

**Model-Based Connectivity Metrics**

Researchers and wildlife managers in many states have employed computer models to identify wildlife concerns along highways, including big game migration routes (Sawyer et al. 2009, Coe et al. 2015), wildlife movement corridors (Benz et al. 2016), WVC hotspots (Ramp et al. 2005, Shilling and Waetjen 2015, Gunson et al. 2011), crucial habitat linkages for focal species (Beier et al. 2008), and ecological connectivity (Theobald et al. 2012). For example, extensive research has found that ungulates use riparian corridors as movement pathways, and models have been developed for many species to statistically determine the explanatory factors that influence WVCs (Gunson et al. 2011). For some focal species and landscapes, researchers have developed robust predictive models that could inform credit valuation, including species distribution models, animal movement models, and habitat-based population viability models. Models linking geographical information systems (GIS) data with population viability models using species demographic data could be applied to evaluate the effectiveness of wildlife connectivity mitigation at stabilizing or maintaining populations (Clevenger 2005). Statistical models such as these and other geospatial landscape connectivity tools have the advantage of being transparent and repeatable and are less subject to differences in opinion or interpretation (Beier et al. 2009).

Habitat connectivity has been modeled from a variety of perspectives (see Kindlmann and Burel 2008 or Rudnick et al. 2012), with some of the most common approaches using graph theory (Pascual-Hortal and Saura 2006), least-cost paths (Adriaensen et al. 2003), circuit theory (McRae et al. 2008), Brownian bridge models (Sawyer et al. 2009), landscape permeability (Anderson and Clark 2012, Gray et al. 2016, Theobald et al. 2012), and linkage designs (Beier et al. 2008). Such models could be used to identify and prioritize the best locations for wildlife connectivity mitigation.

Wildlife connectivity models are often derived from empirical field data on species movement and often incorporate both condition- and function-based metrics to estimate species movement, habitat connectivity, or various other landscape connectivity factors. The models can assess the baseline habitat connectivity of a given location along the highway. Multispecies models also incorporate important criteria such as migration corridors, breeding sites, and seasonal ranges of many focal species. In locations where these analyses have been performed at an appropriate scale and are statistically validated to assess their predictive power on other road sections in similar landscapes, it would be reasonable to value wildlife connectivity mitigation credits based on predicted increases in modeled connectivity for focal species. Mimet et al. (2016) provide a hypothetical model to evaluate the potential increased wildlife connectivity that could result from installing wildlife crossing structures for multiple species. To quantify the value of potential wildlife crossings, a global index of the initial connectivity was computed, then the increase in network connectivity provided by the crossing was estimated. To evaluate multispecies connectivity values, connectivity gains were run through a principal components analysis.

Regional habitat connectivity analyses are important to the development of a crediting strategy for wildlife connectivity mitigation because they provide a starting point for state DOTs to identify potential metrics and available datasets. For example, the California Essential Habitat Connectivity Project (Spencer et al. 2010) used the best available science, data sets, and spatial analysis techniques to identify 192 large remaining blocks of intact habitat or natural landscape linkages to be maintained, such as movement corridors and migration routes required by wildlife. The metrics used to identify these “essential connectivity areas” could be useful for valuing wildlife crossings or other connectivity enhancements; these metrics include the area’s index of ecological condition (see Davis et al. 2003), acreage of protected lands, species diversity, acreage of habitat for listed species, acreage of wetlands, and density of surrounding development. The Vermont Wildlife Linkage Habitat Analysis (Austin et al. 2006) incorporated multiple data layers into a GIS map that includes the ecological value of habitat near highways, roadkill data, development density, land use data, the amount of core habitat surrounding a potential linkage, and other information to predict the location of wildlife linkage habitats in proximity to highways. The results of this analysis produced a wildlife crossing value GIS layer with values from 1 to 10 to rank the relative priority of areas for wildlife crossings within different regions of Vermont (Austin et al. 2006). As state natural resources agencies revise their state wildlife action plans, they are encouraged to analyze wildlife connectivity (Association of Fish and Wildlife Agencies 2012). Wade et al (2015) present various frameworks that state DOTs and natural resources agencies could follow for connectivity planning and detail eight steps for resistance-surface-based modeling (e.g., least-cost paths).

**Avoided Cost Metrics**

Cost-benefit analyses of wildlife connectivity mitigation aimed at reducing WVCs with large ungulates in the United States and Canada have demonstrated that, when installed at suitable sites, crossing structures can simultaneously enhance human safety, preserve wildlife, and save money over the long term (Huijser et al. 2009). In areas where WVCs are numerous, such as regions of the eastern United States with abundant white-tailed deer (*Odocoileus virginianus*), measuring reductions in WVCs could provide a metric for valuing wildlife connectivity mitigation. On average, U.S. motorists had a 1 in 167 chance of colliding with a deer (*Odocoileus* spp.), elk (*Cervus elaphus*), moose (*Alces alces*), or caribou (*Rangifer tarandus*) in 2018, and these WVCs were estimated at 1.33 million annually between July 1, 2017, and June 30, 2018 (State Farm Mutual Automobile Insurance Company 2018).

The increasing development of regional and statewide plans to prioritize WVC hotspots and wildlife linkage areas, such as those in California (Huijser and Begley 2019), Idaho (Cramer et al. 2014), Montana (Huijser et al. 2007), Nevada (Cramer and McGinty 2018), and Oregon (Trask 2009), encourage state DOTs to include wildlife connectivity mitigation into transportation projects because the benefits are often shown to exceed the costs over the life of the project based on the metric of reduced WVCs. Constructing wildlife crossings or other connectivity enhancements at high-priority locations can be effective in terms of the avoided costs (i.e., reduced WVCs), so it would be practical to use avoided cost metrics (i.e., lower costs due to reduced WVCs) to quantify wildlife connectivity mitigation credits.

The most common method for evaluating the effectiveness of wildlife connectivity mitigation at reducing WVCs is to compare the number of WVCs that occurred before and after implementation of the mitigation. Typically, crash data from three to five years before and after implementation are compared (Huijser et al. 2008b). Crash and carcass data regarding collisions with large mammals are available in most states, largely due to property damage and safety concerns (e.g., Garrett and Conway 1999, Hubbard et al. 2000, Waller and Servheen 2005, Farrell and Tappe 2007, Huijser et al. 2008a, Wakeling et al. 2015). WVCs are also well documented at some locations for a variety of smaller species, including mammals (Clevenger et al. 2003, Orlowski and Nowak 2004, Ford and Fahrig 2007); birds (Orlowski and Siembieda 2005); reptiles and amphibians (Rudolph et al. 1998, Carr and Fahrig 2001, Eigenbrod et al. 2008, Roe et al. 2006, Sillero 2008, Elzanowski et al. 2009); and even insects (Rao and Girish 2007). The annual cost of avoided WVCs can be calculated and compared to the cost of the mitigation measure(s) amortized over the projected life time of the project (e.g., Huijser et al. 2009), which could identify locations where wildlife connectivity mitigation credit generation is economically justifiable for improving human safety and benefitting wildlife.

Many state DOTs have existing monitoring programs or have partnered with state natural resources agencies and/or universities to study roadkill and/or WVCs. In some states, where WVCs are a safety concern, data collection for WVC carcasses and crashes is standardized to prioritize highway segments with high WVC rates. Carcass reporting by state agencies is becoming more efficient and accurate as a result of mobile devices (i.e., Utah, Idaho, Arizona) and volunteer reporting (Waetjen and Shilling 2017). In other states, WVC mortalities are often greatly underreported in crash databases (e.g., Donaldson 2017), carcass data collection is inconsistent, and reporting is not centralized. In rural areas of the western United States, accurately quantifying roadkill is costly because of increased technician travel times and intensive data collection (CDFW pers. comm. 2019a). Furthermore, for certain species that are rare or difficult to detect, WVC data may not be numerous enough to use this approach as a basis for mitigation credits without a pre- and post-construction monitoring plan. However, under certain situations and for certain focal species, state DOTs and/or natural resources agencies could use the reduction in WVCs as an accurate metric to develop credits for wildlife connectivity mitigation.

### 2.1.3 Monetary Valuation of Wildlife Connectivity Mitigation Credits

To monetize the value of wildlife crossings or other connectivity mitigation, it is necessary to calculate the value (price) of credits. The economic impacts of WVCs could be an important metric for calculating credit values. Various non-market valuation techniques, including revealed preference techniques, stated preference techniques, or techniques based on poaching fines and restitution could be used to calculate the value of animals that would be restored or maintained by a wildlife crossings or other connectivity enhancement (Land & Water Australia 2005, Duffield and Neher 2019). In the absence of data to value the species that could benefit from a wildlife crossing or other connectivity enhancement, the value of the mitigation credits would need to be calculated based on an accepted unit of measure for other mitigation credits that benefit the same species. For example, where conservation banks exist for listed species, wildlife connectivity mitigation credits could be converted to acres in a conservation bank and calculated as equivalent to the number of acres that could be purchased with the same amount of money as the wildlife connectivity mitigation.

#### Revealed Preferences Techniques

The value of a wildlife mitigation project also could be estimated based on the amount of money that people are willing to spend to use, conserve, or restore the wildlife populations that would benefit from the mitigation. Values are available for consumptive uses of wildlife, and for big game in particular, where hunting license costs and associated hunter expenditures (e.g., Huijser et al 2009) could be used to estimate the dollar value of an animal. Additional expenditures for non-consumptive uses of wildlife (e.g., wildlife watching) could also be considered. Non-consumptive expenditures are significant and have increased from $59.1 billion in 2011 to $75.9 billion in 2016 (USDOI 2017). The 2016 Recreation Use Values Database (Rosenberger 2016) provides a list of 44 economic valuation studies that estimate the value of wildlife watching in the United States and Canada from 1958 to 2015.

#### Stated Preference Techniques

A common method used to estimate the value of environmental resources involves asking people directly—for example, through a survey—how much they value a good or service. This method discloses people's "willingness to pay" for a good or service, via contingent valuation (see Bateman and Willis 2001). This dollar amount could provide useful information about the economic utility of wildlife connectivity mitigation measures that maintain or enhance wildlife populations. Richardson et al. (2014) used contingent valuation to quantify the economic values associated with roadside bear viewing in Yellowstone National Park, finding that on average, visitors are willing to pay around $41 more in entrance fees to ensure that bears are allowed to remain along roads in the park. This translates to a total willingness to pay of more than $12 million annually across all visitors.

Willingness to pay valuation methods for natural resources have been used mostly for ecosystem services and land protection value estimates, but society may also be willing to pay more to conserve lands that provide vital linkages to wildlife across highways within a larger landscape context of protecting connections between areas of large, high-quality wildlife habitat. Thus, it stands to reason that wildlife connectivity mitigation credits could be greater for wildlife crossings or other connectivity enhancements located adjacent to, or between, protected lands because future development is limited in protected areas. Generally, the more land protected as natural habitat surrounding a wildlife crossing or other connectivity enhancement, the less risk or degree of uncertainty about whether wildlife would use it. Various researchers have estimated both the market and non-market components of ecosystem service values associated with land protection (see Costanza et al. 1997). A survey in Ohio estimated that respondent households were willing to pay $16.80 to $29.16 per year for a conservation easement program to prevent development of a riparian corridor along the Grand River (Blaine and Smith 2006). In the Netherlands, respondents to a survey regarding efforts to reconnect (defragment) two different landscapes provided an average willingness to pay of approximately at $180.00 per respondent (van der Heide et al. 2008). Similar economic valuation efforts could be used by state DOTs to estimate societal preferences for wildlife habitat connectivity. The National Research Council (2004) reported that, given the effort and expense, it was rare to see mitigation valuation or trading based on these econometric techniques. However, these techniques are increasingly in use, especially for cost-benefit analyses to support federal grants to fund projects.

Willingness to pay valuation methods are also widely used to estimate the economic value of natural resources and ecosystem services that are not traded in markets and for which no economic behavior is observable, or the passive use values of natural resources or services (Vincent et al. 1995). Individuals may be willing to pay for the continued existence of wildlife through the preservation of habitat connectivity because wildlife and their habitat have intrinsic values to society even if a person does not use or visit the resource. Duffield and Neher (2019) summarize the current literature of passive use value estimates for selected species and populations that could be of interest to state DOTs. They reported several dozen species-specific passive use value estimates from the literature, but reported many gaps associated with species most at risk in road collisions. They estimate per-animal passive use values for elk ($37,000); grizzly bear ($4,133,000); wolf, inside/outside protected areas ($2.0 million/$56,500); and desert tortoise ($8,200). Duffield and Neher (2019) note that there are no cases where state DOTs have used passive use values for valuing wildlife affected by transportation infrastructure, there are other types of infrastructure projects that have relied on passive use value estimates.

**Monetizing Wildlife Connectivity Mitigation Credits**

Assigning a monetary value to environmental attributes that are lost and gained provides a common scale for the valuation of transportation project impacts (Kagan et al. 2014). Given that the monetary value of certain focal species could be calculated, wildlife connectivity mitigation credits could conceivably be quantified to provide a common scale for the valuation of transportation project effects on those species. For example, the number of individual wildlife, by species, that would potentially benefit from wildlife connectivity mitigation could be approximated from studies on animal movement using telemetry, track beds, remote cameras, or other appropriate monitoring methods (e.g., Clevenger et al. 2008). Mitigation credits could then be generated based on the value of those individual animals.

State DOTs commonly monetize impacts such as accidents or vehicles emissions and evaluate highway projects with cost-benefit analyses, such the Cal-B/C model used by Caltrans (Booz-Allen & Hamilton, Inc. 1999). Similarly, state DOTs could quantify the monetary impacts of wildlife connectivity mitigation in terms of property damage, human injury, and/or death by measuring wildlife mortality and/or WVCs before and after construction of a wildlife crossing or other connectivity enhancement. Bissonette et al.

(2008b) estimated that the average cost of WVCs involving deer in Utah was $3,470 per incident, which included the costs of human fatalities, human injuries, vehicle damage, and the loss of the deer killed. In British Columbia, insurance claims related to WVCs averaged approximately $1,600 per claim in 2000, with estimated clean-up costs of an additional $25 to $350 per accident, depending on the size of the mammal (Sielecki 2010). Donaldson (2017) calculated that deer-vehicle collisions are the fourth costliest of the 14 major collision types in Virginia, averaging more than $533 million per year. In California, the total annual cost (2017) of WVCs was estimated to be at least $307 million, up 11% from 2016, based on observations of reported traffic incidents and carcasses. If accidents that are claimed to insurance companies, but un-reported to police, were included, Shilling et al. (2018) estimated those costs could be as high as $600 million per year. These cost estimates from California are much higher than those provided by other researchers, with property damage estimated at $17,343 per WVC and human injury costs of $105,228 and $506,217 for minor and major injuries per WVC, respectively.

Researchers have analyzed studies of wildlife crossings to identify the threshold value of ungulate-vehicle collisions (per year) at which various wildlife connectivity mitigation measures would start to generate economic benefits in excess of their costs (i.e., the break-even point). Huijser et al. (2009) evaluated the costs and estimated effectiveness of various mitigation measures for reducing WVCs and developed a cost-benefit model as a decision-support tool for determining the most cost-effective mitigation measures to reduce WVCs and improve wildlife habitat connectivity. They estimated that the costs (in 2007) for a seasonal wildlife warning sign was $3,728; an underpass with fencing and jump outs was $538,273; an animal detection system with fencing and gaps was $836,113; and an overpass with fencing and jump outs was $719,667. Huijser et al. (2009) then estimated the average overall cost of WVCs for ungulates in 2007 as $6,617 for deer, $17,483 for elk, and $30,760 for moose. These costs included vehicle repair, human injuries, fatalities, accident attendance, value of the animal to hunters, and carcass removal. The average annual cost per kilometer of building and maintaining fencing with wildlife underpasses and jump outs was $18,123. Given these costs, the break-even point for one of the most effective mitigation measures, fencing with underpasses on a divided four-lane road, was estimated for deer, elk, and moose as 3.2, 1.2, and 0.7 WVCs per kilometer per year, respectively. Thus, if a road section has costs (i.e., WVCs) that exceed these threshold values, then the benefits of fencing with wildlife underpasses on a divided four-lane road would exceed the costs over a 75-year time period. Similarly, previous cost-benefit analyses by Reed et al. (1982) estimated that wildlife fencing in combination with underpasses required 11.3 deer-vehicle collisions per kilometer per year before the benefits of the mitigation exceed the costs. This threshold is higher primarily because it does not include the costs associated with human injuries and fatalities, or the values of wildlife that are not easily monetized like hunting. More recently, Gagnon et al. (2015) used the costs from Huijser et al. (2009) to demonstrate that savings accrued by constructing wildlife crossings, fencing, and other connectivity enhancements for reducing collisions with elk would exceed the costs to implement such measures within five years. Likewise, Ford et al. (2011) used the value for deer presented by Huijser et al. (2009) for bighorn sheep (*Ovis canadensis*) to show the cost-effectiveness of various lengths of highway fencing at reducing WVCs. These analyses demonstrate that wildlife connectivity mitigation can be cost-effective when valued in terms of human safety and property damage, even on highway sections with relatively low incidences of WVCs.

For condition-based metrics, calculating the price per credit and quantifying the number of wildlife connectivity mitigation credits would be more speculative because of the lack of a biological metric on which to base the predicted ecological gain from a wildlife crossing or other connectivity mitigation measure. As a result, credit quantification could be arbitrary and potentially inconsistent, so it would be useful to base the valuation of credits on the cost of a wildlife crossing or other connectivity enhancement. For example, the USFWS (2012b) *Panther Habitat Assessment Methodology* uses the average cost of FDOT bridge/box culvert crossings as the basis for calculating the number of conservation bank acres required for purchase to mitigate the impacts of increased traffic from development projects on the Florida panther (see section 5.2).

For model-based connectivity metrics, the monetary valuation or quantification of credits would require several assumptions about the effectiveness of a wildlife connectivity mitigation measure at either maintaining or enhancing wildlife passage across a highway or conserving or recovering focal species. Model-based metrics to value wildlife connectivity are not explicitly linked to the ecological gain that would result from a wildlife crossing structure or other connectivity enhancement. These metrics could thus be categorized as practice-based metrics, whereby “a conservation outcome is expected to be achieved by implementing a specific practice” (i.e., mitigation measure) and its implementation is a “proxy for performance” (Pindilli and Casey 2015).

**Poaching Fines and Restitution**

Lastly, the value of wildlife could be approximated by the restitution paid for animals that are unlawfully taken, whether enforced by USFWS for violations of the ESA (81 *Federal Register* 41862) or by states for poaching (Cramer et al. 2014, 2016). Edwards (2017) provides restitution values for illegally taken game species in the United States, with the most common species being wild turkey (*Meleagris gallopavo*), white-tailed deer, black bear, and elk.

## 2.2 ONLINE SURVEY

The authors conducted an online survey to elicit information from experienced practitioners on how they were developing approaches, protocols, and requirements for wildlife connectivity mitigation (Appendix A). The information gathered from the survey also provides insight into the current use of mitigation credits for wildlife crossings and other connectivity enhancements, and if applicable, the valuation metrics and methods used. Because the literature review revealed limited information about valuation metrics and methods for wildlife connectivity mitigation crediting, the survey was also developed to identify the most-experienced individuals willing to discuss their specific programs and projects in follow-up phone interviews.

### 2.2.1 State DOT Experience with Wildlife Connectivity Mitigation

The online survey revealed a consensus among state DOT and natural resources agency practitioners that dedicated wildlife crossings provide a direct benefit to wildlife and a highway safety improvement to the public by reducing collisions with large animals. The survey results also showed that the development of crediting and valuation systems for wildlife crossings is in the early stages in less than a handful of states. However, there is keen interest in the development of mitigation programs for wildlife connectivity. More than half of the respondents to the survey indicated that, if their state provided the option to have a credit system for wildlife connectivity mitigation, they would take advantage of such a system. Survey respondents stated that a wildlife connectivity mitigation crediting program would offer increased flexibility for state DOTs to satisfy compensatory mitigation needs for wildlife connectivity impacts.

State DOTs are developing individual approaches to address wildlife connectivity through mitigation measures, which tend to be specific to a focal species within a transportation project corridor and/or geographic region. Respondents to the survey largely confirmed (84%) that their state incorporates wildlife connectivity assessment and mitigation considerations early in the transportation project planning process and the transportation project programming and design processes. At the project level, wildlife connectivity mitigation is typically considered collaboratively during the environmental review process and usually involves state DOTs engaging with federal and state natural resources agencies with jurisdiction over wildlife resources. When federally listed threatened or endangered species could be affected, USFWS is consulted. In several states, respondents said that wildlife advocacy groups were also included in planning efforts involving wildlife connectivity assessments or evaluations of mitigation needs related to specific transportation projects.

Survey respondents indicated that several states are exploring the valuation or crediting of wildlife connectivity mitigation. Most are in the early development or exploratory stages such as the Transportation Sub-team of the Panther Recovery Implementation Team in Florida. California's wildlife and transportation agencies are piloting a wildlife connectivity mitigation credit approach and have signed a credit agreement for one project, the Laurel Curve Project (see section 5.1) (Caltrans and CDFW 2017).

The online survey also revealed that several state DOTs have experience with advance mitigation and/or in-lieu fee mitigation programs, which demonstrate their familiarity with non-traditional mitigation instruments to address impacts on wildlife. These programs often require collaboration with multiple stakeholders. An example of an in-lieu fee program is one that was set up through a memorandum of agreement between FHWA, Colorado DOT (CDOT), and USFWS for the threatened Canada lynx in Colorado (FHWA et al. 2015). The program allows highway projects to contribute to a fund rather than providing mitigation for adverse effects on lynx habitat under the ESA. The required financial contribution is calculated as a specified percentage of total project construction costs using a sliding scale and is tied to the type and severity of the adverse effect that the transportation project is expected to have on lynx. The total financial contribution to the fund is capped at 5% of the total construction costs. Funds would accumulate until they could be spent on mitigation that would provide a significant conservation benefit to Canada lynx habitat and movement throughout the state. Funds cannot be indefinitely sequestered; they must be spent wholly, or in part, at least once every three years.

CDOT has an Advance Mitigation Program, the Shortgrass Prairie Initiative, that provides programmatic clearance for CDOT activities in the eastern third of Colorado for 20 years through the acquisition of lands and conservation easements that support several rare, threatened, and endangered species. As part of this initiative, CDOT, USFWS, and FHWA have invested resources in more comprehensive and proactive wildlife habitat conservation that would otherwise be spent as project-by-project mitigation.

California respondents indicated that Caltrans has a new framework to implement wildlife connectivity mitigation through its Advance Mitigation Program. This program dedicates at least $30 million annually for four years to the planning and implementation of advance mitigation projects. Since January 2017, CDFW’s new RCIS program provides a collaborative planning process through which wildlife connectivity mitigation projects can be identified and qualify as eligible for advance mitigation credits.

Obstacles to a broader nation-wide adoption of advance mitigation programs or mitigation crediting systems for wildlife connectivity were apparent from the survey and interviews. Obstacles mostly related to the frequency of need for advance mitigation credits in a region and the lack of funding for both the development of a wildlife connectivity mitigation crediting program and advance mitigation approaches to evaluate impacts and prioritize wildlife connectivity mitigation. The lack of a standard set of metrics and methods to calculate wildlife connectivity mitigation credits for wildlife, the topic of this study, was also an apparent hurdle to overcome.

### 2.2.2 Examples of Crediting Approaches to Wildlife Connectivity Mitigation

Ninety-one percent of respondents to the survey strongly confirmed that mitigation credits for impacts on wildlife connectivity impacts are not available to state DOTs. Only one state DOT, Caltrans, has participated in a proof-of-concept effort to coordinate the development of advance wildlife connectivity mitigation, whereby credits can be applied as compensatory mitigation for the ecological impacts of other Caltrans transportation projects. Since that undertaking, new state legislation became effective whereby, under specific conditions, including the availability of a CDFW-approved RCIS, wildlife crossing structures may qualify as enhancement actions for advance mitigation crediting.

Few other examples were identified where mitigation credits have been generated from wildlife crossings and other connectivity enhancements, or where credits have been available to mitigate other kinds of transportation project impacts. FDOT provided an example of calculating mitigation credits by evaluating habitat connectivity under the Florida Department of Environmental Protection's (FDEP) Uniform Mitigation Assessment Method (UMAM) (see section 5.3).

## 2.3 Practioner Interviews

For further insight into state DOT efforts to identify the mitigation values of wildlife crossings and other connectivity enhancements, follow-up phone interviews were conducted with survey respondents in Arizona, California, Colorado, and Florida with extensive experience with wildlife connectivity mitigation in their state (Appendix A). Interviewees included:

- Eight state DOT planners or environmental managers
- Seven wildlife biologists at state natural resources agencies
- One federal transportation agency staff

### 2.3.1 Legal, Planning, and Policy Framework Considerations

Interviews with experienced practitioners revealed that state DOTs and natural resources agencies are increasingly collaborative in their efforts to reduce WVCs and provide safe passage for wildlife across highways. This cooperation is driven by the need to simultaneously improve public safety, reduce the substantial costs of WVCs, conserve big game, and provide passage for smaller sized wildlife. The major barriers to further collaboration are staff and funding shortages and the different timescales for transportation and wildlife planning processes.

**Support for Advance Mitigation**

Advance mitigation was generally viewed by those surveyed as a useful tool for state DOTs to satisfy compensatory mitigation needs for potential transportation project impacts on wildlife connectivity. Practitioners are interested in opportunities to establish advance mitigation programs or to receive credit for needed wildlife connectivity mitigation during transportation planning and prior to transportation project impacts occurring.

California's Advance Mitigation Program (Caltrans 2018) is the only example of a program that has performed wildlife connectivity mitigation to establish credits, to be applied as mitigation for other infrastructure projects (see section 5.1), and interviews with Caltrans practitioners focused largely on this program. California's Advance Mitigation Program planning process includes three steps. First, a statewide assessment is performed to estimate the potential compensatory mitigation needs. Next, regions are identified that could potentially provide advance mitigation opportunities that meet the Advance Mitigation Program objectives, and a regional advance mitigation needs assessment is performed. Lastly, candidate advance mitigation projects are scoped and proposed at the District level for possible funding through the Advance Mitigation Program (Caltrans 2018). Caltrans compensatory mitigation needs are predicted for endangered species and other permitting requirements. However, it is possible that continued research in California, such as recent WVC analysis focused on mule deer (*Odocoileus hemionus*) (Huijser and Begley 2019), will help Caltrans make informed decisions on the potential implementation of advance mitigation measures at the most problematic highway locations based on human safety, biological conservation, and economics.

Under specific conditions, fish passage and wildlife crossing structures may be eligible for advance mitigation crediting under new state regulations codified about the same time as Caltrans Advance Mitigation Program. The California legislature passed a law, effective in 2017, officially creating the CDFW RCIS program (Fish and Game Code §§ 1850–1861). CDFW (2018) recently released its *RCIS Program Guidelines*. The RCIS program provides a new framework to guide proactive, landscape-level conservation planning that differs from the existing regulatory authority of the California Natural Community Conservation Planning program and provides for additional mitigation actions beyond those allowed under California’s existing conservation and mitigation banking programs. An RCIS is voluntary and is intended to be a multi-stakeholder plan that identifies and prioritizes actions, including mitigation measures, that would promote conservation of species, habitats, and other natural resources to facilitate advance mitigation, such as for transportation projects. An RCIS includes an evaluation of habitat connectivity for focal species and identifies wildlife linkages where wildlife connectivity could be maintained or enhanced (CDFW 2019).

For the implementation of advance mitigation projects consistent with an RCIS, Fish and Game Code authorizes the creation of MCAs between CDFW and another party. MCAs could be used to define a crediting mechanism whereby wildlife crossing structure construction could be used for offsetting effects of future transportation projects. The RCIS enabling legislation allows mitigation credits created under an MCA agreement with CDFW to be used, sold, or in special circumstances, transferred. Because CDFW’s RCIS program is the only one of its kind in the United States, it has a flexible framework that allows for project proponents/sponsors to propose the metrics used to calculate mitigation credits as long as they provide a sound rationale (CDFW pers. comm. 2019a). Under the CDFW (2019b) Draft MCA Guidelines—to be incorporated as section 5 of the RCIS Program Guidelines (CDFW 2018)—an MCA must: (1) describe the unit of measurement (e.g., acres, linear feet) for credits; (2) provide a credit evaluation that explains the approach used to formulate the quantity (number) and value (price) of credits; and (3) provide a credit table that shows the number and type of credits to be released according to specific regulatory uses (CDFW 2019b). CDFW’s Draft MCA Guidelines also detail the development of credit release schedules, the transfer and use of credits, and the reporting requirements to account for the proposed credits.

A wildlife biologist with CDFW (pers. comm. 2019a) highlighted three advantages of advance mitigation under its newly created RCIS program: (1) it would provide a cheaper and faster mitigation crediting process than traditional mitigation because approval is only required by one agency (CDFW); (2) it would allow for greater flexibility in the types of credits generated and methods used to quantify them; and (3) it would allow for temporary wildlife mitigation, such as non-permanent habitat enhancements, to qualify as eligible for mitigation credits. This information aligns with the findings of Sciara et al. (2017) that advance mitigation programs could produce overall cost savings to state DOTs, largely from reduced permitting delays and improved coordination and consultation with regulatory agencies.

To assess impacts of future transportation projects under an Advance Mitigation Program, GIS methods have been developed to aggregate predicted terrestrial impacts of road projects in California (Thorne et al. 2009). Such methods do not address the impacts of transportation projects on highway connectivity, but Thorne et al. (2009) suggest that habitat connectivity information could be included from regional conservation plans and/or wildlife connectivity models to identify target areas for preservation.

**Concerns About Mitigation Measures Within the Right-of-Way**

Some state DOTs have concerns about encumbrances that could arise after construction of mitigation measures within the highway right-of-way that they are responsible for maintaining. If the credit area conflicted with a future maintenance need or highway expansion, then any loss of credit-generating action would need to be replaced as part of the overall compensation. Likewise, issues with wildlife connectivity mitigation within the right-of-way could arise if a wildlife crossing structure needed to be replaced or repaired as a result of reduced function. Although federal funds often largely pay for the construction of wildlife crossing structures, state DOTs bear the cost burden of maintenance (ARC Solutions 2017). Mitigation structures must be maintained and repaired to ensure their continued use and effectiveness (Cramer and Bissonette 2005). Imposing such requirements for the maintenance of wildlife connectivity mitigation projects was noted as a legal concern by a practitioner at FDOT (FDOT pers. comm. 2019). However, a California practitioner suggested that, because the mitigation would be within the right-of-way, it would be easier for Caltrans to uphold maintenance requirements when compared to other offsite mitigation projects (Caltrans pers. comm. 2019).

#### Interagency Coordination

Although institutional challenges remain for creating a regional ecosystem framework that aligns state DOT goals and objectives with those of natural resources agencies, numerous state DOTs have effectively coordinated with their respective state natural resources agencies to identify and prioritize landscape linkages or wildlife corridors. For example, CDOT and other agencies developed a multi-agency Memorandum of Understanding (CDOT et al. 2008) for the I-70 Mountain Corridor programmatic environmental impact statement, which outlines a shared vision for enhanced wildlife connectivity and reduced WVCs. An interagency technical advisory committee of biologists from multiple state and federal agencies (A Landscape-Level Inventory of Valued Ecosystem Components or ALIVE) was formed to develop a landscape-based approach to consider wildlife needs (CDOT et al. 2008). The ALIVE committee analyzed ecosystem connectivity and identified 13 high-priority locations where evidence suggested that the highway impedes the migration, movement corridors, or zones of dispersal for elk, mule deer, bighorn sheep, and Canada lynx. The committee recommended mitigation measures that included enhancing existing or creating new wildlife crossing structures. Collaborative approaches such as this were widely supported by the practitioners interviewed, although it was apparent that some state DOTs have better working relationships with USFWS and their state natural resources agencies than others.

#### Funding Obstacles

Practitioners consistently pointed to the lack of funding as one of greatest obstacles to constructing wildlife crossings and other connectivity enhancements; the lack of funding is supported by other research (Kociolek 2014, Ament et al. 2015) and is largely because funding for transportation projects gives priority to motorist safety over wildlife conservation. In general, WVCs are less severe than other types of crashes, resulting in fewer deaths and serious human injuries (Huijser et al. 2007). Thus, the relative costs of WVCs are usually less than the costs of other types of vehicle collisions. Under most state DOT funding programs with accounting methods that do not value wildlife, wildlife connectivity mitigation projects often do not receive funding because they would provide less economic benefit than other motorist safety projects (CDOT pers. comm. 2019). According to practitioner survey responses, the ecological benefits of wildlife connectivity mitigation are currently not given high priority in most highway projects, which supports the need for an alternative mitigation approach that could integrate conservation priorities.

### 2.3.2 Potential Valuation Metrics for Wildlife Connectivity Mitigation Credits

Methods to calculate mitigation credits for a given wildlife connectivity mitigation project are not well developed and the survey conducted as part of this research found that only Caltrans and FDOT have generated mitigation credits for wildlife crossing projects.

**Support for Function-Based Metrics**

Generally, planners and environmental managers at state DOTs support using function-based metrics to value mitigation credits for wildlife crossings and other connectivity enhancements and applying the generated credits (via debits) to the impacts of other transportation projects. This support aligns with research by Bennett et al. (2017) that recommends credits for mitigation markets incorporate measures of ecological function and biodiversity. However, practitioners provided limited examples. The best example is FDOT's incorporation of habitat connectivity benefits into the wetland mitigation assessment for focal species that use wetlands and watercourses as movement corridors between large blocks of intact habitat (see section 5.3).

When asked about the function-based metrics potentially used to value mitigation credits, in general, most practitioners interviewed responded that "it would depend on the species." Because different species have widely variable life histories, habitat requirements, and dispersal abilities, accommodating the needs of multiple species is inherently difficult (Mimet et al. 2016), and practitioners noted that quantifying mitigation credits for multiple focal species would be challenging. If function-based metrics were used to value wildlife connectivity mitigation credits, practitioners generally agreed that most feasible metrics would be based on attributes related to the ecological improvement for a single focal species, rather than multiple species. When asked if wildlife mitigation credit valuation should be calculated based on a standard set of metrics for landscape-level wildlife connectivity or as a tailored set of metrics for single species or multispecies, Caltrans staff responded, "Because the needs of small, protected species such as tortoises, turtles, kangaroo rats, salamanders and frogs are much different than the regional context for landscape-level connectivity, it would be more appropriate in California to have either just a tailored set of metrics or a combination of these and landscape-level metrics. It is highly unlikely that any one set of metrics would meet our needs in California" (Caltrans pers. comm. 2019)

For most function-based metrics that could be used to quantify credits for a wildlife connectivity mitigation project, monitoring animal through-passage of a wildlife crossing or other connectivity enhancement would be required. If the release of mitigation credits depended on such a performance standard, a Colorado practitioner suggested that a standard monitoring approach would be necessary to evaluate whether it was effective at providing the promised levels of through-passage to focal species (CDOT pers. comm. 2019). Although most wildlife crossings built in the United States have been monitored via remote cameras to verify their usage by focal species (e.g., Cramer and Hamlin 2016), standard protocols are not typically used (Caltrans pers. comm. 2019, FDOT pers. comm. 2019). In a review of the state of the practice over a decade ago, Cramer and Bissonette (2005) found that a limited number of the 460 terrestrial wildlife crossing structures in the United States were monitored for effectiveness.

**Support for Avoided Cost Metrics**

Mitigation credits could be quantified for wildlife connectivity mitigation by calculating an increase in motorist safety via a measured reduction in WVCs. This metric is commonly used in the literature to evaluate the effectiveness of wildlife crossings (see section 2.1.3), and practitioners suggested it as a proxy for quantifying improved motorist safety. A California practitioner highlighted the value of roadkill data collection for identifying areas where mitigation credit values should be highest for wildlife crossings and other connectivity enhancements in locations that maintain or restore genetic connectivity for desert bighorn sheep (CDFW pers. comm. 2019a). Because many state DOTs have existing programs for collecting data about WVCs, in certain situations, this metric could be among the most straightforward metrics available to calculate mitigation credits for wildlife connectivity projects. In California, Shilling et al. (2018) evaluated WVCs and identified stretches of highway where WVC are most likely. They reported five valuable recommendations that would apply to state DOTs seeking to apply mitigation credits for wildlife crossings that use a motorist safety metric as part of the credit calculation: (1) systematically collect and share WVC data; (2) require collection and analysis of WVC data for transportation projects before they are approved and funded; (3) protect driver safety and wildlife by building WVC-reduction projects; (4) form new partnerships among university and non-governmental organization (NGO) scientists, citizen groups, and local agencies interested in reducing WVC impacts; and (5) systematically evaluate effectiveness of WVC reduction to keep improving.

**Need for Consistent Credit Quantification**

Whatever metrics and methods are used to calculate mitigation credits for wildlife connectivity mitigation, the practitioners interviewed generally agreed that there should be consistent quantification of the benefits to focal species from wildlife connectivity mitigation (credits) and the impacts of mitigated transportation projects (debits). Ideally, the metrics used to calculate wildlife connectivity mitigation credits would be easy to measure, based on the focal species' biology, and result from collaboration and agreement among stakeholders.

**Need for Empirical Data**

The valuation of wildlife connectivity mitigation explored by this study is improved when empirical biological data exist for focal species on a road-by-road basis to identify the most cost-effective decisions. Decision makers need information on the ecological importance of each linkage area and ways to identify the most important linkages. Typically, a suite of focal species and associated habitats are identified that have the greatest need for enhanced connectivity. Developing a crediting system for wildlife connectivity mitigation would require a robust analysis of focal species' habitat and movement patterns, including migration corridors, breeding sites, and seasonal ranges, and how highways affect these topics.

Highly mobile species that require large habitat areas are the most sensitive to highways (Mimet et al. 2016). These species also include many large mammals that are economically valuable for recreation and/or more costly in terms of vehicle damage and human injuries due to their large body size. Thus, where highways negatively affect big game and/or large mammalian carnivore populations, metrics to quantify the value of wildlife connectivity mitigation could likely incorporate their value to society and/or the cost of WVCs.

If credit release were to be based on wildlife crossing performance, monitoring would need to follow a rigorous study design that includes pre-construction versus post-construction comparisons of animal movements across highways (see section 4.6). One of the most straightforward metrics used to evaluate the effectiveness of a wildlife connectivity mitigation project would be to measure increased driver safety using the number of reduced WVCs after implementation as a proxy. To quantify WVCs, most state DOTs have data-collection protocols in place. NDOT provided a summary of state DOT efforts in the western United States to collect and map WVCs and roadkill, map wildlife linkages, and create prioritization processes (see table 55 of Cramer and McGinty 2018). In Colorado, CDOT has standard operating procedures for collecting data about all accidents involving wildlife from the Colorado State Patrol (CDOT pers. comm. 2019). In Arizona, WVC data are collected via a smartphone application, Survey123 for ArcGIS, which is shared among state agency staff (Arizona Game and Fish Department pers. comm. 2019). South Dakota DOT uses a similar smartphone application to collect and store WVC data (Cramer 2017).

Also, perhaps more than any other impact of highways on wildlife, roadkill is clearly quantifiable, and roadkill surveys could be used to monitor the effectiveness of a wildlife connectivity mitigation project. Colorado has operating protocols for collecting carcass information any time CDOT staff handles roadkill or wildlife injured by a vehicle (CDOT pers. comm. 2019). Utah Division of Wildlife and Utah DOT (2019) collect similar data and publish them online. However, standardized road survey protocols are not available, and only a handful of studies have sought to identify the optimal sampling approach needed for roadkill surveys of different taxa (Bager and Rosa 2011, Costa et al. 2015, Ford et al. 2011). Several biological considerations must be considered to use roadkill as a metric for evaluating the effectiveness of wildlife connectivity mitigation, including the relationship between roadkill and surrounding wildlife population abundance, and the road avoidance behavior of some species in response to traffic volume (i.e., roadkill rates decrease as traffic volume increases because animals are less likely to cross the road) (Eberhardt et al. 2013, Teixeira et al. 2017).

**Data Limitations**

The lack of data about rare or elusive focal species could be an obstacle to developing mitigation credits for a wildlife connectivity mitigation project. For example, in Colorado, a CDOT practitioner suggested that, for low-density, wide-ranging focal species such as Canada lynx, it would be difficult to quantify mitigation credits for a wildlife connectivity project because the degree of benefit to Canada lynx would be difficult to measure. While the highway crossing behavior of Canada lynx has been studied in Colorado (Crooks et al. 2008, Baigas et al. 2017), the biological benefits of various highway crossing structures to Canada lynx remains unpredictable. Canada lynx have been documented crossing at-grade over Colorado highways on numerous occasions, but CDOT has not documented the species' use of existing wildlife connectivity mitigation projects in the state (CDOT pers. comm. 2019). This uncertainty, combined with the technical difficulties of effective on-site mitigation, led CDOT to develop an option to use a percentage of total construction costs to calculate funds required for contribution into a Canada lynx in-lieu fee fund (see section 2.2.1).

Video surveillance (Dodd et al. 2007) or noninvasive genetic sampling (Clevenger and Sawaya 2009, Dixon et al. 2006), potentially combined with spatial capture-recapture models (Royle et al. 2017), could quantify increased habitat connectivity provided by wildlife connectivity mitigation; however, these methods are not certain to be effective for species like Canada lynx. Furthermore, Clevenger (2005) suggests that if population-level impacts are used as the metric for valuing wildlife connectivity mitigation, elusive carnivores and other large mammals would not be suitable focal species because of their demographic characteristics and sample size limitations. Many other factors also affect a population, so it would be difficult to isolate the effect of wildlife connectivity mitigation measures.

A practitioner in Colorado also suggested that data limitations for common, relatively easy-to-monitor species could present an obstacle to valuing wildlife connectivity mitigation. Colorado Parks and Wildlife has collected global positioning system (GPS) collar locations from numerous big game studies, but the lack of data from certain herds, including migration routes and seasonal habitat use, would be an obstacle to developing metrics to value wildlife crossing structures (CDOT pers. comm. 2019). This is despite the fact that big game are among the most easily monitored wildlife because of their large size and visibility. Practitioners with CDOT also mentioned the need for current data about focal species and how they interact with highways because observations and expert opinions gathered over decades may not necessarily reflect current conditions. New development or other human impacts occur rapidly and could have altered the movement of focal species, increasing uncertainty about the future effectiveness of proposed wildlife connectivity mitigation measures (CDOT pers. comm. 2019).

**Adopting Existing Wetland Mitigation Assessment Protocols for Credit Quantification**

To demonstrate the improved wildlife connectivity provided by wildlife crossing structures, FDOT has incorporated the habitat connectivity metrics provided by FDEP's UMAM (Bardi et al. 2004). Although this legally mandated tool is focused on mitigation requirements for impacts to wetlands and surface waters, it includes metrics that value the ecological connectivity provided by drainage culverts and bridges associated with streams and wetlands. Further detail on this approach is provided in section 5.3.

# 3.0 POTENTIAL VALUATION METRICS FOR WILDLIFE CONNECTIVITY MITIGATION CREDITS

One criticism of mitigation banking is the general lack of standardization of credit quantification and metrics. For conservation bank credits, which are typically based on a simple metric such as acres of habitat, the methods to quantify the value of the credits often differ among species, and even between USFWS field offices. Pindilli and Casey (2015) reported that the standardization of metrics for mitigation credits would reduce the administrative burden, increase transparency, and better facilitate the creation of markets for mitigation credit trading. Therefore, it is essential that state DOTs think critically about the unit of measurement (i.e., metric) that could be used for wildlife connectivity mitigation credits and provide a clear evaluation that explains the approach used to formulate the quantity (number) and value (price) of the metric chosen.

This study reveals many potential metrics for valuing wildlife connectivity, but none that have been consistently applied by researchers. As discussed in the literature review above in section 2.1.2, the metrics explored in this study that are potentially useful are summarized in Table 2, including their potential unit of measurement and notes regarding their applicability. These metrics could be used to either quantify the benefits to wildlife from a wildlife crossing or other connectivity enhancement or measure the adverse effects to wildlife from other transportation projects. Each metric is assigned into one of four categories, which are defined as:

- *Condition-based connectivity metrics*—measurements that value wildlife connectivity or assess transportation project impacts based on the physical, chemical, and biological attributes of a system, such as various highway or ecosystem characteristics
- *Function-based connectivity metrics*—measurements that value wildlife connectivity or assess transportation project impacts based on wildlife habitats and ecosystem processes, such as the acreage of suitable habitat or patterns of wildlife movement
- *Model-based connectivity metrics*—measurements that value wildlife connectivity or assess transportation project impacts based on computer models that combine elements of function- and condition-based metrics to estimate wildlife connectivity
- *Avoided cost metrics*—measurements that value wildlife connectivity or assess transportation project impacts based on the economic value of wildlife or human life and/or property

Metrics to value wildlife connectivity mitigation credits would likely be ecosystem- and species-specific. As discussed in section 2, the literature review, online survey, and practitioner interviews revealed that the ecological implications of wildlife connectivity mitigation measures would differ based on the species and ecosystems adjacent to a highway. The factors to consider would include the life history of the focal species and their habitats, the availability of research on wildlife crossings for those species, and the amount of existing data on WVCs and focal species occurrences. For many potential focal species, information about their habitat use and movement ecology is sufficient to quantify one or more potential metrics to measure the conservation value of a wildlife crossing or other connectivity enhancement (e.g., the acres of accessible suitable habitat that would be maintained or restored or the genetic diversity of a population that would be increased or maintained). On a national level, however, identifying universal metrics or quantification methods for valuing wildlife connectivity mitigation is infeasible.

Because site-specific field data are lacking in many locations and given tight project budgets and schedules, many state DOTs may be inclined to use condition- and function-based metrics that measure conservation values rather than crossing performance. Alternatively, state DOTs may use model-based

**Table 2. Potential metrics to value wildlife connectivity mitigation, their potential units of measurement, and notes regarding their applicability**

| Category | Metric to Value Wildlife Crossings | Unit of Measurement for Mitigation Credits | Notes on Applicability to State DOTs[a] |
|---|---|---|---|
| **Condition-based** | Area of highway footprint within the highway crossing zone used by focal species [b, c] | Acres of impervious surface or highway project boundary | Caltrans used this metric for SR-19 Laurel Curve in Santa Cruz County, California. It assumes that, within the zone where wildlife connectivity would be improved, increasing permeability of a larger highway footprint would equate to greater benefits to focal species, which may not necessarily be true. With respect to impacts, the converse is also assumed, where transportation projects with larger footprints would require more credits. |
| | Overall project costs [b, c] | A percentage (%) of total transportation project costs | CDOT used this method to calculate mitigation funds ($) required for contribution into a Canada lynx in-lieu fee program. |
| | Habitat area used by focal species [b, c] | Acres of focal species' habitat | Wildlife connectivity mitigation that affects larger areas of suitable habitat for focal species could generate more mitigation credits because greater numbers of individual animals could be affected. |
| | Number of lanes [b, c] | Area of new highway lanes | Assumes that increasing permeability across more lanes of a highway would equate to greater benefits to focal species. Credits could be applied to transportation projects that decrease highway permeability and increase WVC risk due to increased roadway capacity. |

| Category | Metric to Value Wildlife Crossings | Unit of Measurement for Mitigation Credits | Notes on Applicability to State DOTs[a] |
|---|---|---|---|
| **Condition-based** | Traffic volume [b, c] | AADT or vehicles per hour | Species-specific data about animal movement over highways with different AADT volumes would be necessary to quantify potential benefits or impacts to a given focal species. More credits could be generated for wildlife connectivity mitigation on high-volume highways or applied to transportation projects that increase traffic. |
| | Roadway barriers [c] | Length of fence, jersey barriers, median structures, or other potential barrier to the movement of focal species | Credits could be applied to transportation projects that decrease highway permeability through the creation of permanent structures like jersey barriers or retaining walls. |
| | Speed limit [c] | Increased speed limit | Credits could be applied to transportation projects that decrease highway permeability and increase WVC risk due to increased speed limits. |
| **Function-based** | Safe passage of focal species [b, c] | Number of individual animals of focal species crossing highway | Methods have been developed to accurately monitor the number of individuals crossing highways or using wildlife crossings via cameras, track pads, and radio telemetry. Studies could be designed to quantify the number of individual animal crossings in paired treatment and control areas pre- and post-construction, but such studies are difficult because many other factors also influence wildlife. |

| Category | Metric to Value Wildlife Crossings | Unit of Measurement for Mitigation Credits | Notes on Applicability to State DOTs[a] |
|---|---|---|---|
| **Function-based** | Genetic interchange of focal species [b, c] | Change in genetic diversity in comparison to current generation | Connectivity among populations reduces the negative effects of inbreeding and genetic drift, but it takes relatively little exchange between populations to maintain genetic diversity. DNA profiling of individuals using wildlife crossings or crossing highways is a technique that could be carried out in a relatively short period of two to three years, and methods exist to monitor many species via noninvasive genetic sampling (e.g., hair snares). DNA assignment testing could be used to quantify the change in connectivity via enhanced or reduced genetic structure of focal species populations. |
| | Conservation of rare, threatened and endangered species [b, c] | Acres of suitable habitat connected or fragmented | There are no laws that require compensatory mitigation for adverse effects on wildlife connectivity, except for cases where federally listed or state-listed threatened and endangered species are affected. Thus, wildlife connectivity mitigation credits would most likely be focused on mitigating for impacts to regulated species (i.e., threatened and endangered animals). |
| | Migration of focal species [b, c] | Number of individuals of affected migratory species crossing highway | Effective wildlife connectivity mitigation should allow animals to travel and migrate to meet their requirements for seasonal habitats. Metrics to evaluate success include passage rates and the number of animals that use a wildlife crossing or other connectivity enhancement. |
| | Dispersal of focal species | Number of dispersing juveniles crossing highway | Effective wildlife connectivity mitigation should provide for demographic movement, which occurs when there are dispersing individuals from one sub-population to another. Dispersing individuals could be identified by noninvasive genetic sampling (e.g., hair snares). |

| Category | Metric to Value Wildlife Crossings | Unit of Measurement for Mitigation Credits | Notes on Applicability to State DOTs[a] |
|---|---|---|---|
| **Function-based** | Population size(s) of focal species [b, c] | Number of affected individual animals of focal species | Although there is widespread agreement that effective wildlife connectivity mitigation has the potential to enhance population viability of species impacted by roads, few studies have empirically addressed this and there are many confounding factors. Demonstrating population-level effects would require substantial time and funding, especially for wide-ranging, elusive species such as large carnivores. |
| | Habitat quality for focal species [b, c] | Quality of connected or fragmented habitat to focal species | Wildlife connectivity mitigation that connects or fragments high-quality habitat for focal species could generate more mitigation credits than measures that affect low-quality habitat. Standard or accepted protocols would need to be used to access habitat quality. |
| **Model-based** | Landscape connectivity models [b, c] | Validated model values | Credits could be generated or applied based on predictions from wildlife connectivity models for multiple focal species using graph theory, least-cost paths, circuit theory, landscape permeability, and linkage designs. Confidence in the application of models to the valuation of credits would be higher if the model results have been validated to assess their predictive power on other road sections in similar landscapes. |
| | Species-specific models [b, c] | Validated model values | For some focal species, researchers have developed animal movement models and habitat-based population viability models, among others, that could inform credit quantification for wildlife connectivity mitigation. Metrics based on statistical models and other geospatial landscape connectivity tools have the advantage of being transparent and repeatable. |

| Category | Metric to Value Wildlife Crossings | Unit of Measurement for Mitigation Credits | Notes on Applicability to State DOTs[a] |
|---|---|---|---|
| | Traffic forecasting models and/or predictive models of land development [b, c] | Predicted AADT or vehicles per hour | Researchers have combined traffic demand forecasting models with wildlife connectivity models to predict the crossing locations where future mitigation would be necessary for grizzly bears. |
| **Avoided Cost** | Property damage, human injury, and/or death from WVCs [b] | Number of WVCs over a specified time period (seasonal or annual) | Crash and carcass data could be used to calculate the potential safety improvement and/or ecological gain to focal species. Existing state DOT monitoring approaches could be used to track performance standards. |
| | Highway maintenance costs due to reduced WVCs [b] | Number of roadkill carcasses over a specified time period (seasonal or annual) | Most state DOTs have data-collection protocols in place, and roadkill surveys could quantify the number of decreased WVCs to monitor the effectiveness of a wildlife connectivity mitigation project. |
| | Economic value of hunted or watchable wildlife affected by WVCs [b, c] | Number of roadkill carcasses of focal species over a specified time period (seasonal or annual) | The value of credits generated could be based on the economic value of the wildlife species affected, using the cost of the animals that are unlawfully taken (i.e., restitution costs for poaching), hunting license costs and associated hunter expenditures, expenditures by non-consumptive uses such as wildlife watching, and passive use values. |

[a] Notes on applicability are based on the authors' findings from the literature review and interviews with experienced practitioners, as detailed in section 2.0; references are not repeated.
[b] Metric potentially used to quantify the benefits to wildlife from a wildlife crossing or other connectivity enhancement (i.e., credits).
[c] Metric potentially used to measure the adverse effects to wildlife from other transportation projects (i.e., debits).

metrics because they could incorporate existing ecological datasets and results from prior modeling efforts to predict ecological gain for multiple species. When evaluating potential metrics to value wildlife connectivity mitigation, it would be useful for state DOTs to assess their potential importance using an approach recommended by the National Research Council (2000) for evaluating ecological indicators. This would involve state DOTs evaluating the following nine criteria for each potential metric, as modified for wildlife connectivity mitigation:

- *General importance*—Is the metric informative about major changes in wildlife connectivity and associated ecological processes that affect wide areas?
- *Conceptual basis*—Is the metric based on principles of wildlife connectivity that are well understood and generally accepted?
- *Reliability*—Has the metric been demonstrated from previous experience as being successful at quantifying changes in wildlife connectivity?
- *Temporal and spatial scales*—Is the metric appropriate for the scale of the focal species' movements and life history and/or the scale of the landscape for which wildlife connectivity is evaluated?
- *Statistical properties*—Is the metric sensitive enough to detect important changes in wildlife connectivity but not so sensitive that changes are masked by natural variability?
- *Data requirements*—Can data for quantifying the metric be collected with a reasonable level of effort and existing technology?
- *Skills required*—Can the metric be accurately measured in a straightforward process by individuals without highly technical, specialized knowledge?
- *Data quality*—Can the metric be measured with clear documentation of sampling and analytical methods describing exactly how it is calculated?
- *Robustness*—Can the metric be used in the future given anticipated technological changes or scientific advance?
- *Costs, benefits, and cost-effectiveness*—Is the cost of collecting data for quantifying the metric reasonable, or is there a less expensive metric that would yield the same information?

Kindlmann and Burel (2008) argue that "there is an urgent need for comparing and generalizing studies of landscape connectivity," and that new connectivity metrics are needed "that incorporate both information on species-specific movement behavior and landscape structure, and that are relatively simple to calculate." Until such metrics are developed and more widely adopted, the selection of metrics to value wildlife connectivity mitigation will remain a challenge for state DOTs. Despite challenges to valuing wildlife connectivity mitigation credits, state DOTs and their partners could develop accurate metrics to value wildlife connectivity mitigation credits under certain circumstances. State DOTs would need to evaluate the current state of knowledge about wildlife connectivity issues in their state, weigh the costs and benefits of wildlife connectivity mitigation, and determine if it makes economic and ecological sense to develop guidelines identifying suitable metrics and quantification methods to value wildlife connectivity mitigation measures. In addition, any metrics used for valuing wildlife connectivity should be based on sound science and follow a transparent and consistent approach (Pindilli and Casey 2015).

The metrics most readily converted into mitigation credits are those based on accurate measurements of project impacts and mitigation site benefits (Kagan et al. 2014). It would be constructive to create an interagency working group(s) of biologists, engineers, and planners from state DOTs and other state and federal agencies to evaluate potential metrics, as discussed below in section 4.2. Further transparency could also be provided if the working group's recommended metrics and quantification methods were analyzed under a planning process that includes an opportunity for public review and commenting. This process would address one of the largest issues of concern for mitigation banking practitioners, according to Pindilli and Casey (2015), which is a lack of transparency in pricing or standards for estimating credit values.

# 4.0 CONSIDERATIONS FOR DEVELOPING A PROGRAM FOR ADVANCE MITIGATION AND CREDITING FOR WILDLIFE CONNECTIVITY

The process to establish, apply, and manage advance mitigation credits for wildlife connectivity would have similarities to the well-established conservation banking program authorized by USFWS and the wetland mitigation banking program administered by USACE. State DOTs could review the lessons learned from mitigation banking a decade ago according to the U.S. Government Accountability Office (2005), and the subsequent U.S. Environmental Protection Agency and USACE guidance in the 2008 compensatory mitigation rule (73 *Federal Register* 19594). The rule strengthened the planning, implementation, and management of compensatory mitigation by requiring measurable, enforceable ecological performance standards, regular monitoring, and oversight of wetland mitigation banks.

The following sections present a general discussion of topics for state DOTs to consider in developing a program for advance mitigation and crediting for wildlife connectivity. In addition to the regulatory environment and policy considerations discussed previously, developing a crediting strategy for wildlife connectivity mitigation will require coordinating with stakeholders; developing an interagency working group; defining the types of wildlife connectivity mitigation measures that could generate credits; defining an appropriate geographic service area; establishing strategies to manage credits and debits; monitoring performance post-construction; and managing long-term commitments.

## 4.1 Coordinated, Regional Wildlife Connectivity Planning as a Prerequisite

Developing an Advance Mitigation Program poses unique challenges, such as a need for collaboration at a regional scale across agencies and jurisdictional boundaries, as well as the coordination of funding and schedules. This is particularly true when various stakeholders, such as state DOTs and natural resources agencies, do not share the same missions or priorities (Rudnick et al. 2012). State DOTs that have experience with advance mitigation programs, such as North Carolina, Florida, Washington, and California (Lederman 2017), would have an advantage over states without advance mitigation programs because their transportation planners and biologists would have experience with integrative and collaborative planning at the landscape level. These efforts could provide the type of ecological connectivity information necessary to identifying the most useful metrics for valuing wildlife connectivity mitigation.

## 4.2 Interagency Working Group Formation and Roles

Establishing a dedicated interagency working group to address wildlife connectivity mitigation, at either a statewide or state DOT regional or district level, would bring together transportation planners with the local experts in wildlife ecology, transportation planning, highway safety, and highway engineering. This collaborative effort would advance wildlife connectivity by providing a forum for stakeholders to discuss their concerns and prioritize objectives to ultimately develop a shared vision for incorporating wildlife connectivity into transportation plans and projects.

The creation of interagency working groups would address step 1 of the IEF, which includes building support among stakeholders to establish a regional or statewide planning process that can integrate wildlife connectivity enhancement and maintenance into transportation planning and funding efforts. To develop metrics and credits for wildlife connectivity mitigation, it would be most effective for state DOTs to follow the nine steps of the IEF as elaborated in *An Ecological Approach to Integrating Conservation and Highway Planning, Volume 2* (NAS 2012). These steps could be applied to wildlife connectivity mitigation as follows:

Once potential metrics are identified for priority wildlife crossing locations, the working group would need to identify a scientifically defensible quantification method for the number of credits and identify performance standards to ensure that those credits represent viable wildlife connectivity outcomes. At the outset, a site visit would be necessary to confirm site eligibility, the estimation of credits, and the adequacy of performance standards and monitoring plans. The working group could then provide guidance on the acceptable methods to value wildlife connectivity mitigation.

### 4.3 Potential Mitigation Measures that could be Credited for Wildlife Connectivity

To mitigate unavoidable impacts on wildlife from a transportation project, the type of mitigation measures eligible for crediting would need to be effective for the focal species. In addition, using credits for wildlife connectivity mitigation should logically only be used in situations where there is a reasonable level of certainty that the biological benefits to the affected population(s) would be sufficient to mitigate impacts of future transportation projects.

To evaluate the effectiveness of wildlife connectivity mitigation measures, Huijser et al. (2008a), in a report to the U.S. Congress, performed a review of more than 34 WVC mitigation methods used by state DOTs to reduce WVCs, such as warning signs, vegetation removal, fencing, and wildlife crossing structures. The estimated effectiveness varied from as low as a 26% reduction in WVCs (seasonal wildlife warning signs) to a 100% reduction in WVCs (overpasses). The most effective mitigation measures were identified as "proven" and, where feasible and appropriate, mitigation credits that could be implemented would include: (1) public information and education; (2) wildlife fencing; and (3) underpasses and overpasses with fencing. However, the report only looked at the measures' effectiveness in reducing crashes, not in improving connectivity for wildlife.

Fencing is an integral component of effective wildlife crossings (Romin and Bissonette 1996). Fences alone, while effective at reducing WVCs, can actually reduce connectivity. Fences used with animal detection systems are limited because they only address large animals. Wildlife crossing structures, combined with fencing that separates wildlife from motorists and directs animals to the crossing structures, reduce WVCs for all types of wildlife and increase connectivity (Andis et al. 2017).

Some non-structural wildlife connectivity mitigation measures have been proven to reduce WVCs effectively; these measures include public information and education and animal detection-driver warning systems (i.e., Gagnon et al. 2019). Lastly, local guidance regarding the effectiveness of various wildlife connectivity mitigation should be consulted before applying mitigation credits to various types of mitigation measures. Several state DOTs have developed specific guidelines, such as Caltrans' (2009) *Wildlife Crossings Guidance Manual* and Vermont DOT's *Vermont Transportation & Habitat Connectivity Guidance Document* (Vermont DOT 2012); an FHWA report by Clevenger and Huijser (2011), *Wildlife Crossing Structure Handbook Design and Evaluation in North America*, details numerous solutions for effective wildlife connectivity mitigation.

In general, based on the above findings, the types of mitigation measures that are proven effective for reducing WVCs and allowing for safe passage of animals across the highway include the following:

- new wildlife crossing structures (e.g., overpasses or underpasses) with fencing and jump outs
- retrofitting existing drainage structures (e.g., bridges and culverts) with fencing and jump outs for larger animals or other physical barriers for reptiles and amphibians; and,
- animal detection-driver warning systems at crosswalks with fencing (for large mammals only).

## 4.4 Definition of Geographic Areas for Credit Application (Service Areas)

Like wetland mitigation banks and species conservation banks, the geographic area where credits could be used for mitigation must be defined. The service area to use credits generated from a wildlife connectivity mitigation measure would likely be defined by the overall range of the focal species or regional population(s). Service areas could also be based on the ecosystems or habitat types used by focal species or an ecoregion. A service area for a species conservation bank is typically determined in the banking agreement. For example, CDFW's *Draft Mitigation Credit Agreement Guidelines* for its RCIS program, state that "the MCA must include an ecologically based explanation on how the service area was determined" (CDFW 2019b).

## 4.5 Credit Management and Debiting

Credit issuance under conservation banks approved by USFWS must use the same system (i.e., units of measure) to quantify both the biological values of mitigation sites and the adverse impacts of the development for which the credits could be used as mitigation (USFWS 2003, USDOI 2013). In some instances, mitigation ratios are used to ensure that mitigation is proportionate to the impact being mitigated. For example, in theory, if a transportation project would affect the movement of an estimated number of grizzly bears, then the metric to value credits for a wildlife connectivity mitigation measure should benefit an equal or greater number of grizzly bears. USFWS (2003) notes that the use of mitigation ratios must be based on a sound biological rationale that is easily explained, readily understood, and consistently applied. Determining equivalency between mitigation credits and the impacts of transportation projects is well established for mitigation banks and conservation banks and is generally based on what is being measured or monitored, such as the acreage of wetlands or habitat, or the number of breeding pairs of a species. There is greater uncertainty about equivalency between the ecological gain from a wildlife connectivity mitigation measure and the ecological loss to connectivity from a future transportation project. No straightforward approach yet exists, and practitioners interviewed from California, Colorado, and Florida did not have experience using any metrics that could be evaluated for equivalency.

Before creating a system for wildlife connectivity mitigation banking, demand for such mitigation must be assessed. In the *Results from a Survey of Conservation Banking Sponsors and Managers*, USDOI (2018) found that one of the most substantial obstacles for conservation banking is that demand for bank credits is often weak. Therefore, state DOTs would be advised to analyze their future transportation projects to identify mitigation needs, including the types of impacts that could reasonably be mitigated by wildlife connectivity mitigation. This needs assessment would be step 4 of the IEF (NAS 2012). As an example of current practice, Caltrans, through its Advance Mitigation Program, is performing a statewide advance mitigation needs assessment every two years that will estimate the potential impacts of future planned transportation projects that are part of a 10-year transportation planning document. Impacts are determined by overlaying assumed transportation project footprints with natural resource data layers. The location of forecasted impacts will be used to determine regions for conceptualizing advance mitigation projects. Once the statewide needs assessment is completed, Caltrans will develop regional advance mitigation assessments within the identified regions, identify its understanding of conservation goals and objectives, identify conservation plans and recovery plans for its species of mitigation need, and identify existing mitigation opportunities. Although the statewide needs assessment does not forecast impacts on wildlife connectivity from new transportation infrastructure, increased traffic, or maintenance of the state highway system, wildlife connectivity will be addressed in the regional advance mitigation needs assessment (Caltrans pers. comm. 2019).

## 4.6 Post-Construction Monitoring

Like other forms of compensatory mitigation, monitoring the effectiveness of wildlife connectivity mitigation is essential to ensure they meet their objectives of reduced impacts on wildlife, increased highway crossings, improved motorist safety, or other targets. A properly designed monitoring program that includes pre-defined performance targets would be required (see Appendix D of Clevenger and Huijser 2011). This would be especially true if a modeling approach were taken, as monitoring would verify if the predicted ecological improvement from a wildlife crossing or other connectivity enhancement sufficiently mitigates impacts from other transportation projects.

In wetland mitigation banks and species conservation banks, performance standards, or credit release criteria, are typically required to be met before credits can be sold. However, for wildlife connectivity mitigation, the lack of standard criteria and protocols for monitoring performance standards could be an obstacle to implementing a mitigation crediting program. Although most wildlife crossings in the United States are monitored to evaluate their effectiveness at providing wildlife passage, according to practitioners surveyed, few projects have had clearly defined success criteria other than documenting their use by wildlife. Standard monitoring protocols would need to be developed that are cost-effective to implement and to conclusively measure performance standards for focal species. State DOTs, as transportation agencies and not natural resources agencies, may not have the expertise to develop performance standards and would be advised to consult with state and federal natural resources agencies with permitting authority.

Currently, only a few states have developed standardized methods for monitoring wildlife crossings, including Montana, Idaho, Oregon, Washington, and Utah (Kintsch and Cramer 2016). The scope of most monitoring elsewhere is typically narrow, focusing primarily on larger carnivores and ungulates, and almost exclusively on use of the structures. In Colorado, few practitioners have followed standardized protocols, and only some have documented the presence of focal species (Kintsch and Cramer 2016, CDOT pers. comm. 2019). For other types of wildlife connectivity mitigation, such as fence construction or removal, retrofits to existing drainage structures, or jump outs, the lack of standard monitoring protocols would make establishing a performance-based credit release schedule difficult. In such cases, a practice-based performance standard could be agreed upon as adequate, based on previous practices, research or studies, and well-founded assumptions that maintaining or enhancing wildlife connectivity at a particular site would result in species recovery or protection, rather than actual observations.

Another consideration when identifying metrics for wildlife connectivity mitigation is the duration of required monitoring. CDFW (pers. comm. 2019a) suggested that, under the RCIS program, future MCAs for wildlife connectivity mitigation would likely include short-term monitoring to evaluate performance standards (i.e., credit release) and long-term monitoring and maintenance to ensure continued effectiveness. The monitoring specified in a MCA would be determined by the metric used to quantify credits and the biology of the focal species and should consider any available past research. Monitoring studies of wildlife crossings structures and other connectivity enhancements have shown that, in general, wildlife use increases slowly over time, over as many as 10 years and varies by species. Thus, for some species, short-term monitoring for less than this duration may mislead stakeholders about the ultimate effectiveness (i.e., ecological gain) of a wildlife connectivity mitigation project (Huijser et al. 2008b).

In summary, although some state DOTs have existing WVC and roadkill data-collection programs that could be used to calculate mitigation credits and monitor wildlife connectivity mitigation, the use of such data would depend on the focal species and may not be applicable to many taxa. In certain situations, these metrics could reasonably be used to value wildlife connectivity mitigation that benefits big game, particularly when used in combination with GPS collar data. However, for many focal species that are rare or difficult to monitor, developing cost-effective performance standards for credit release would present an obstacle that would need to be overcome before mitigation credits could be generated.

## 4.7 Long-term Commitments

Implementing wildlife connectivity mitigation may not be enough by itself to ensure that a focal species is maintained or conserved over the long term. For this reason, a primary obstacle to the siting and construction of wildlife crossings in Florida has been the reluctance by the State of Florida to locate crossings when unprotected private lands exist on either side of a proposed crossing location (USFWS 2005). Thus, in most cases, it would be necessary to include provisions for state DOTs to acquire adjacent lands on either side of the wildlife crossings and facilitate their long-term protection for conservation purposes. Likewise, state DOTs have a long-term commitment to maintain wildlife connectivity mitigation within the right-of-way to ensure the future effectiveness of the mitigation. Like wetland banking, if credits were generated from a wildlife connectivity mitigation measure, then the credit owner would likely be required to maintain the wildlife crossing or other connectivity enhancement to retain any unapplied credits or to demonstrate the persistence of benefits from credits applied to other transportation project.

A major advantage of developing a wildlife connectivity mitigation crediting program would be the creation of a dedicated funding source for wildlife crossings and other connectivity enhancements. However, establishing a sustainable statewide funding source for wildlife connectivity mitigation could be a significant hurdle to overcome in many states. In California, Thorne et al. (2015) cautions that advance mitigation funding should not rely on funding sources that could expire. They suggested that, for advance mitigation funding, mandating that a percentage of all project funding be committed to compensatory mitigation would provide Caltrans with funding to purchase mitigation credits before projects have been programmed.

# 5.0 CASE STUDIES

## 5.1 CASE STUDY #1—CALTRANS ADVANCE MITIGATION PROGRAM AND THE LAUREL CURVE PILOT PROJECT

### 5.1.1 Background

California's Road Repair and Accountability Act of 2017 officially established the Caltrans Advance Mitigation Program to oversee the administration, planning, delivery, implementation, and tracking of Caltrans advance mitigation projects (Caltrans 2018). Codified in California Streets and Highway Code (SHC) 800 et. seq., advance mitigation projects eligible for funding consist of authorized activities pursuant to SHC §800.6(a), if Caltrans determines that the activity would provide appropriate compensatory mitigation of the anticipated potential impacts of planned transportation improvements. In general, the authorized activities pursuant to SHC §800.6(a), consist of (1) purchasing existing advance mitigation credits from conservation or mitigation banks or contributing to an HCP; or (2) establishing advance mitigation credits through existing regulatory processes and/or instruments (i.e., mitigation bank prospectus and instrument) (Caltrans pers. comm. 2019).

Prior to the Advance Mitigation Program's formal establishment, the Laurel Curve Wildlife Connectivity Project piloted Caltrans' first advance mitigation project that established mitigation credits for constructing a wildlife crossing structure and fencing that may be applied to meet the compensatory mitigation needs of future transportation projects. The connectivity project was triggered by WVCs on a stretch of U.S. Highway 17 (Keeley et al. 2018). The Laurel Curve Project has been supported by research and data collected by a regional partnership among Caltrans, CDFW, county natural resource management agencies, land trusts, university researchers, and NGOs. Multiple species, especially mountain lions (*Puma concolor*) regularly use a corridor where Caltrans will install a wildlife crossing structure across the four-lane highway in the Santa Cruz Mountains, between the San Francisco Bay and Santa Cruz areas. Funding sources include, but are not limited to, Advance Mitigation Program funds from the 2016 State Highway Operation and Protection Program (SHOPP). Implementation of the crossing structure is slated for completion in 2020.

The Laurel Curve wildlife crossing will enhance permeability across Highway 17, which was later identified as a conservation action for habitat connectivity in the *Draft Santa Clara County RCIS* (Santa Clara Valley Open Space Authority 2017). Before the RCIS program was established, Caltrans and CDFW signed a "pilot" credit agreement in 2017 for Caltrans' financial contribution to the Laurel Curve Project (Caltrans and CDFW 2017). The Laurel Curve Project Credit Agreement established credits under the California Environmental Quality Act (CEQA) for a wildlife crossing structure and fencing that can be used to mitigate impacts of future transportation projects. The credit agreement allows Caltrans to apply wildlife crossing credits as compensation for the CEQA-significant impacts of transportation projects performed under the SHOPP within a specific service area. As CEQA-lead agency, Caltrans determines when credits may be applied to a transportation project. Funded through the SHOPP, the credits must be applied to SHOPP-funded transportation projects and may not be transferred or sold outside Caltrans (Caltrans pers. comm. 2019). Caltrans' financial contribution to the Laurel Curve Project and its associated credit agreement, is one of the 12 projects funded through the 2016 SHOPP.

### 5.1.2 Mitigation Crediting

The Laurel Curve Project Credit Agreement included a methodology reviewed by CDFW for establishing the credits associated with the installation of the new wildlife crossing (Caltrans and CDFW 2017). For this valuation of credits, Caltrans used a simple structural approach to calculate the total number of credits as 368, using the following explanation: "For the purposes of tracking and accounting, a credit was identified as being 0.1 acre." The methodology to determine the number of credits generated was calculated as "the footprint of the highway reach" (36.8 acres) was divided into 0.1-acre credits, yielding 368 credits or 10 credits per acre (Caltrans and CDFW 2017). Valuing credits as equivalent to 0.1 acre was based on the fact that California mitigation banks often sell credits in this increment. This approach did not explicitly consider ecological conditions of the site, so the process does not directly measure the conservation gain from the project; however, the placement of the crossing is based on the research and data collected by the regional government, educational, research, and NGO partnership described above and hence is based on a putative increase in connectivity due to changing (increasing) the highway's permeability.

Credits established by the Laurel Curve Project will be debited as compensation for future transportation projects with significant impacts to wildlife under CEQA, as determined by Caltrans, the lead agency. The Caltrans and CDFW Credit Agreement specifies the types of potential impacts to which the project's CEQA credits could be applied (debited) and provides notes about their use, presented in attachment B, table B-1 of the agreement, and provided in Table 3 (Caltrans and CDFW 2017). Although CEQA credits only require Caltrans' internal approval to be applied to a transportation project, as a proof-of-concept, the credit agreement anticipates a future situation where, for example, ESA credits are issued, and agency permitting staff would have actual approval authority (Caltrans pers. comm. 2019). The agreement also defined the service area where eligible future transportation projects will be able to use the CEQA credits. U.S. Department of Agriculture, Forest Service ecoregional maps, other wildlife habitat data, and predictive models were used to define an appropriate service area.

**Table 3. Debiting guidelines for future transportation projects using credits generated from the Laurel Curve Wildlife Habitat Connectivity Project**

| Type of Potential Impact to Wildlife | Applicable Transportation Project Type | Application of CEQA Credit(s) | Notes |
|---|---|---|---|
| **SHOPP** | | | |
| Repair and replacement of existing barriers without wildlife enhancements included | Collision severity reduction, guardrail upgrades, upgrade median barriers | Not applicable | This is an example of maintaining a barrier and this scenario is not applicable to Caltrans projects funded through the SHOPP. When maintaining an existing barrier does not result in additional impacts above baseline conditions, it is not a significant impact under CEQA. |
| Impacts from improvements of existing state highway system roads that that may decrease permeability of existing roads.<br><br>Impacts of less | Safety Improvements (e.g., curve corrections and re-alignments, lane or shoulder widenings); construction of guardrails<br><br>Roadway | Credits will be applied on a project-by-project basis.<br><br>10 credits per acre impacted OR<br><br>14 credits per lane mile impacted<br><br>(see Attachment A for | CEQA significance would be determined on a project-by- project basis.<br><br>Avoidance and minimization measures are still required and determined on a project-by-project basis during |

| Type of Potential Impact to Wildlife | Applicable Transportation Project Type | Application of CEQA Credit(s) | Notes |
|---|---|---|---|
| than 1 acre, such as permanent loss of roadside habitats during road construction. | rehabilitation (e.g., road stabilization or shoulder rehabilitation), pavement preservation, pavement rehabilitation, drainage system restoration<br>Major damage restoration (emergency opening)<br>Major damage restoration (permanent restoration)<br>Roadside safety improvements<br>Slope stabilization | conversion) | transportation project planning and environmental review.<br>When semi-permeable metal beam guardrail and three-beam median barriers are replaced with concrete, permeability may decrease.<br>Caltrans may decrease permeability and discourage or redirect wildlife crossing due to adjacent land use(s) and/or road engineering constraints.<br>Credits may be useful to local agencies where, based on a local entity's significance criteria, permeability has been unavoidably significantly impacted. |
| **State Transportation Improvement Program** | | | |
| Impacts from improvements to state highway system roads that would increase traffic speeds or road capacity, resulting in greater danger to wildlife attempting to cross | Construction of express lanes, lane additions, new interchange construction or interchange reconfiguration are examples of State Transportation Improvement Program projects. | To be determined by separate future agreements | CEQA significance would be determined on a project-by- project basis.<br>Avoidance and minimization measures are still required and determined on a project-by-project basis during transportation project planning and environmental review. |
| Impacts from new highways or major transportation features | Construction of express lanes, lane additions, new interchange construction or interchange reconfiguration are examples of State Transportation Improvement Program projects. | To be determined by separate future agreements | CEQA significance would be determined on a project-by-project basis.<br>Avoidance and minimization measures are still required and determined on a project-by-project basis during transportation project planning and environmental review. |

Source: Caltrans and CDFW (2017)

Lastly, it is important to note that, regardless of whether advance mitigation is in place, Caltrans transportation projects will still proceed under standard environmental and permitting processes and must demonstrate avoidance and minimization of environmental impacts prior to considering the use of compensatory mitigation (Caltrans 2018). Caltrans would still consult with USFWS and CDFW about on-site effects to federal- and state-listed species and incorporate any recommended or required avoidance and minimization measures determined on a project-by-project during project planning and environmental review (Caltrans and CDFW 2017). In cases where adverse impacts to wildlife connectivity are unavoidable, on-site mitigation could still be performed. The types of Caltrans transportation projects that would likely purchase credits would be existing alignments that provide limited opportunity for avoidance and minimization (Caltrans pers. comm. 2019). In cases where adverse impacts on wildlife are unavoidable, on-site mitigation could still be performed. If a transportation project manager can find compensatory mitigation at a lower cost, Caltrans expects that they would choose that mitigation. Thus, for an individual transportation project to justify the expense of wildlife connectivity mitigation credits, the cost of any alternative compensatory mitigation credit/opportunity would need to be about the same or more.

### 5.1.3 Lessons Learned

Under the Advance Mitigation Program framework, Caltrans demonstrated that it has been able to take ecosystem and landscape-level concerns into account (Sciara et al. 2015b), which bodes well for conserving wildlife connectivity via mitigation crediting. Advance mitigation has also been shown to reduce delivery times for projects in California by 1.3 to 5 months (Sciara et al. 2017). The Laurel Curve Project Credit Agreement describes how Caltrans may apply wildlife crossing credits as compensation for the CEQA-significant impacts of transportation projects performed under the SHOPP in a specific service area. As the CEQA-lead agency, Caltrans determines when credits may be applied to a transportation project. Funded through the SHOPP, the credits must be applied to SHOPP-funded transportation projects and may not be transferred or sold outside Caltrans.

Caltrans believes that advance mitigation funds could be used for wildlife crossings if there were a crediting mechanism that (1) is acceptable by an agency with permitting authority; and (2) establishes credits where the credit cost is competitive with other mitigation source costs (Caltrans pers. comm. 2019). Strategies that facilitated the implementation of the Laurel Curve Project were the collection of extensive wildlife data from camera traps, collar data, roadkill, and linkage models (Caltrans pers. comm. 2019). A media campaign and land trust partners securing adjacent land were also important (Keeley et al. 2018).

The approach taken by Caltrans to generate credits for the Laurel Curve Project did not directly measure the ecological improvement from the project. However, the project was a proof-of-concept effort to demonstrate the framework for developing credit agreements for wildlife crossing structures, and how credits generated from a wildlife crossing could be applied as mitigation for future transportation projects. Although other function-based or model-based metrics could have been used, a condition-based metric was straightforward, repeatable, and inexpensive to calculate. Caltrans practitioners acknowledged that other metrics could have been used that relate to the ecological gain from the project (Caltrans pers. comm. 2019). CDFW's RCIS program is now in place and will enable future credit agreements to be developed in California for wildlife connectivity mitigation measures under the CEQA and other regulations under their authority, and future transportation projects can use the credits to satisfy compensatory mitigation requirements. CDFW (pers. comm. 2019) anticipates that future MCAs for wildlife crossing structures and other connectivity mitigation measures will consider other factors to quantify ecological gain, such as improved access to breeding sites or improved gene flow.

## 5.2 Case Study #2—Florida Panther Crossing Projects

### 5.2.1 Background

The Florida panther, a subspecies of mountain lion, is a federally listed focal species for wildlife connectivity mitigation. Collisions with Florida panthers are not a high safety risk for drivers, but collisions with vehicles are a leading cause of Florida panther deaths. The prioritization of Florida panther connectivity mitigation has been driven by biological requirements of the subspecies rather than motorist safety. Data from GPS-collared Florida panthers showing travel corridors and panther-vehicle collisions have been the primary data source for identifying the locations of wildlife crossing structures (FDOT pers. comm. 2019). Smith et al. (1999) developed a decision-based GIS model for FDOT road improvement projects associated with road mortality of wildlife and other environmental impacts that is integrated to other state environmental initiatives and programs for conservation and recreation land protection. This decision-based priority model has enabled FDOT, in coordination with USFWS, to identify potential wildlife crossing projects according to the conservation needs of Florida panthers,

### 5.2.2 Mitigation Crediting

USFWS provided guidelines to FDOT for determining the appropriateness of including wildlife crossings (upland or wetland) and/or exclusionary devices (fencing, walls, temporary barriers, etc.) on proposed FDOT projects or on existing highways as retrofits (USFWS 2015). These guidelines recommend that “wildlife crossings and/or exclusionary devices should only be considered when the project is a capacity improvement that involves the addition of travel lanes.” FDOT previously explored the idea of implementing wildlife crossings or retrofits to existing structures as mitigation measures for Florida panthers. However, although three conservation banks have been finalized within the Florida panther’s breeding range and connectivity across highways is a primary focus for the species’ conservation, USFWS does not allow wildlife crossings to qualify for compensatory mitigation for panther habitat loss. Although wildlife crossings reduce the likelihood that panthers will be struck by vehicles, they do not compensate for habitat lost due to a road project (FDOT pers. comm. 2019). Thus, where appropriate, USFWS requires wildlife crossings for transportation projects that adversely affect the Florida panther and habitat mitigation credit purchases to offset the loss of habitat.

Because some development projects do not cause substantial habitat loss for Florida panther but do generate increased traffic that contributes to panther mortality, USFWS considers increases in traffic an indirect effect from a project (USFWS 2012b). Although USFWS does not provide a mechanism to generate mitigation credits from wildlife crossings, the USFWS (2012b) *Panther Habitat Assessment Methodology* provides a method for calculating mitigation credit requirements for development projects that would indirectly affect panthers via increased traffic. For projects that would increase traffic and reduce highway permeability, the number of mitigation credits are calculated by converting the average cost of a wildlife crossing structure to the equivalent acreage of land that could be purchased for that amount. This methodology is intended to incentivize the construction of wildlife crossings by assessing mitigation credit requirements as follows:

> we are providing a habitat surrogate of 500 acres per year of habitat loss for these types of projects, with a not to exceed value of 2,500 acres over the 5-year period. The 500 acres per year is based on average cost of FDOT bridge/box culvert crossings (3.6 to 5 million dollars) converted to acreage equivalent costs ($8,500/acre). This 2,500-acre habitat surrogate adds an additional 28 acres per panther to the above adjusted base for a new base of 32,951 acre per panther (2,500 [acres] / 90 [panthers] = 28 +288+352+31,923=32,591). Therefore, [USFWS] has added another 0.02 to the base

ratio to address traffic impacts, which could provide an incentive to implement crossings in key locations.

### 5.2.3 Lessons Learned

The method used by USFWS in south Florida to assess mitigation credit requirements due to increased traffic is informative about current efforts to monetize the indirect impacts of transportation projects on a focal species. The approach is unique in that it uses the average cost of a wildlife crossing structure as the reference value (price) for quantifying the acreage equivalent of habitat. Under a crediting system for wildlife connectivity mitigation, the impacts on wildlife from future increases in traffic could be estimated with a similar approach and mitigation credits generated from wildlife crossings or other connectivity enhancements could be applied to compensate for the impacts.

## 5.3 Case Study #3—FDOT State Route 40 Wildlife Connectivity Mitigation

### 5.3.1 Background

State Road 40 (SR 40) bisects large areas of undeveloped natural habitat in central Florida that provide wildlife movement corridors in an increasingly fragmented region. Much of the adjacent land is public, including the Ocala National Forest, Silver River State Park, Heart Island Conservation Area, and Marjorie Harris Carr Cross Florida Greenway State Recreation and Conservation Area. These lands are important to several threatened and endangered or special-status species, including the Florida scrub-jay, red-cockaded woodpecker, eastern indigo snake, sand skink, and Florida black bear. To address wildlife connectivity, FDOT took an innovative approach to incorporate the ecological benefits of enhancing wildlife connectivity at existing drainage structures and dedicated upland wildlife crossings into calculations of project wetland mitigation requirements.

FDOT collaborated with several key stakeholders to evaluate whether improvements to SR 40 would be feasible given the nature and complexity of the wildlife concerns. The result was a memorandum of agreement between FDOT, USFWS, Florida Fish and Wildlife Conservation Commission, and FDEP, referred to as the SR 40 Task Force. A Wildlife Crossing Committee (WCC) was established that included biologists, planners, and wildlife advocates. As the project moved from the NEPA phase into design, the WCC met regularly (Lyon and Houck 2018). The design phase included breaking the NEPA study into four separate design projects, two in Marion County and two in Volusia County.

To address wildlife connectivity mitigation for the SR 40 project, FDOT applied the scoring system of FDEP's UMAM to calculate mitigation credits in terms of the functional gain provided by wildlife crossing structures. Functional gain is the term used to identify the UMAM score a project's overall ecological benefit in the post-construction condition attained and is typically used for wetland mitigation credits requirements and evaluating restoration sites (Lyon and Houck 2018). The UMAM was not specifically used to score wildlife crossings previously, so FDOT had to develop a method for consistently applying it for the SR 40 project.

### 5.3.2 Mitigation Crediting

Wildlife crossing structures (culverts and bridges) were sited specifically to connect existing conservation lands where they abutted the SR 40 corridor. For each proposed crossing structure, an assessment area, or the potentially impacted geographic area, was defined based on the home range or dispersal distances of aquatic or wetland-dependent focal species. The UMAM was then used to determine the mitigation needed to compensate for adverse impacts on wetlands and other surface waters by assessing their ecological functions according to three categories. One category of wetland function, Location and Landscape Support, evaluates an area's value as a corridor for wildlife movement. As defined in Florida Administrative Code, Chapter 62-345,

> The location of the assessment area shall be considered to the extent that fish and wildlife utilizing the area have the opportunity to access other habitats necessary to fulfill their life history requirements. The availability, connectivity, and quality of offsite habitats, and offsite land uses which might adversely impact fish and wildlife utilizing these habitats, are factors to be considered in assessing the location of the assessment area.

The Location and Landscape Support category is intended to specifically address the pre- and post-construction connectivity for wildlife to and from habitats outside the project area. Two of eight attributes for quantifying an area's Location and Landscape Support measure wildlife connectivity, which is scored numerically on a scale from 0 to 10, as not present (0), minimal (4), moderate (7), or optimal (10). These two attributes are:

(1) the extent to which "habitats outside the assessment area represent the full range of habitats needed to fulfill the life history requirements of all wildlife" … and the extent to which these habitats "are available in sufficient quantity to provide optimal support for wildlife;" and

(2) the extent to which "functions of the assessment area that benefit downstream fish and wildlife downstream are not limited by distance or barriers that reduce the opportunity for the assessment area to provide these benefits." (Florida Administrative Code 62-345)

The UMAM scores calculated an increase to the Location and Landscape Support score by 1 point, which translated to a 10% increase in habitat quality due to the inclusion of the wildlife crossings. The number of mitigation credits generated for each wildlife crossing structure, the relative functional gain, was calculated for each assessment area, and adjusted for two additional factors, time lag and risk. Time lag accounts for the time at which the ecological functions are lost due to an impact (e.g., construction) and when the project has achieved the outcome of increased wildlife permeability. A time lag factor was used for wildlife crossing structures that did not include exclusionary fencing to funnel wildlife towards the structure, based on the assumption that, due to the lack of fencing, it would take 3 years to achieve increased wildlife permeability. A risk factor was also incorporated into the calculations for the crossing structures to account for the degree of uncertainty that wildlife would use the structures.

This methodology was used for one of the Volusia County design sections of SR 40. USACE issued a permit for the project in October 2017, which included the following conditions specific to the wildlife crossings: (1) FDOT shall maintain the crossings and fencing areas as initially permitted in perpetuity; (2) post-construction photos are to be collected by wildlife cameras mounted on the crossing structures and will be included in an annual monitoring report; (3) FDOT will perform a monitoring event within 60 days and provide a report to USACE; and (4) FDOT will perform annual monitoring for no less than 2 years and submit a report to USACE within 60 days of the monitoring completion (Lyon and Houck 2018).

On the Marion County sections of SR 40 that cross through the Ocala National Forest and Silver River State Park, based on the same NEPA study, the WCC identified the need for up to 26 additional wildlife crossing structures. However, the same method as described above could not be applied because the proximity of the crossing structures, if assessed the same way, would double or triple count the assessment area of each crossing structure and result in an artificially high relative functional gain. The solution was to overlap the assessment areas into enhancement zones and calculate the UMAM scores accordingly, as multiple wildlife crossing structures would work together to provide wildlife connectivity. The result is one UMAM score for each enhancement zone. This project is currently under review with USACE (Lyon and Houck 2018).

Similar to the SR-40 projects, FDOT also plans to use a proposed wildlife crossing of I-4 as partial mitigation for proposed impacts to waters of the United States (Stantec Consulting Services, Inc. 2019). UMAM was used to quantify the total number of mitigation credits generated from a proposed wildlife crossing structure to demonstrate the benefits to rare species like the Florida panther and black bear. The primary goal of the wildlife crossing will be to restore an important landscape connection for wildlife that was severed by the original construction of I-4 in the early 1960s. Because of the significance of the I-4 habitat fragmentation effect and the potential benefits of a wildlife crossing to upland and wetland species based on the UMAM results, Florida Fish and Wildlife Conservation Commission supported the concept of allocating wetland mitigation credits for this project (Stantec Consulting Services, Inc. 2019).

### 5.3.3 Lessons Learned

The SR 40 project demonstrates that using an existing wetland assessment methodology to calculate mitigation credits can effectively reduce overall mitigation requirements of a large transportation project by valuing the functional gain provided by wildlife crossings or enhancement of drainage structures for safe wildlife passage. Because most transportation projects include culverts and bridges across natural features, there are typically cost-effective opportunities to enhance wildlife connectivity via retrofitting culverts or modifying bridges to better serve focal species. Providing an option to generate mitigation credits for enhancing existing drainage structure would provide state DOTs with a great incentive to mitigate impacts by pursuing proven wildlife connectivity mitigation in locations where many species naturally cross over or under highways. In such situations, the use of UMAM demonstrates that there are existing wetland mitigation assessment methodologies that include useful metrics to value wildlife connectivity mitigation.

UMAM is not the only wetland mitigation assessment methodology that considered wildlife connectivity. In its *Ecological Performance Standards for Wetland Mitigation*, NatureServe (Faber-Langendoen et al. 2008) includes a “Landscape Context” metric as a categorical performance standard for wetlands mitigation, which measures “the percent of unfragmented landscape within 1 km area (non-riverine), or degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems (riverine).” A simple metric such as this could be incorporated into calculations of a transportation project’s mitigation requirements for the benefit of species that use wetlands and watercourses as movement corridors between large blocks of intact habitat.

Also, the formation of an interagency working group focused on wildlife crossings was effective at overcoming many years of disagreement and led to a collaborative solution to incorporate in-kind wildlife connectivity mitigation. The effort exemplifies the first step of an ecosystem approach to developing transportation projects, to “build and strengthen collaborative partnerships” (Brown 2006).

## 5.4 Case Study #4—CDOT West Slope Wildlife Crossing Prioritization

### 5.4.1 Background

Colorado has increasing highway traffic and relatively high WVCs, so CDOT is working diligently to address wildlife connectivity. Colorado does not have any wildlife connectivity mitigation projects that have used a mitigation crediting framework; however, CDOT’s experience with advance mitigation and its planning for wildlife connectivity is a good example of interagency cooperation to develop a consistent strategy for measuring both the relative ecological impacts of transportation projects and the restoration benefits of wildlife crossings and other connectivity enhancements.

CDOT has been identifying WVC hotspots and linkage areas for more than two decades (Barnum 2003, Crooks et al. 2008, Southern Rockies Ecosystem Project 2005). The results of the ALIVE analysis were incorporated into long-term commitments along the I-70 corridor. CDOT recently performed the West

Slope Wildlife Prioritization Study, a regional prioritization of highway segments for wildlife connectivity mitigation across the mountainous western one-third of Colorado, where wildlife connectivity issues are greatest (Kintsch et al. 2019). Due to the potential integration of this effort into CDOT project planning, budgeting, and design, CDOT is performing a similar prioritization of wildlife crossing locations in eastern Colorado (CDOT pers. comm. 2019).

The West Slope Wildlife Prioritization Study is a multi-agency comprehensive approach to valuing future high-priority wildlife connectivity mitigation projects. Note that CDOT practitioners stressed that the agency mission is focused on motorist safety (CDOT pers. comm. 2019), so WVCs were the primary metric of concern, in combination with migration and habitat data for mule deer and elk. The main objective for CDOT was to identify wildlife-highway conflict areas under both current conditions and future land use and traffic scenarios to identify where mitigation could have the greatest impact on reducing WVCs. The West Slope Prioritization Study produced the following products: (1) a prioritized list and maps of highway segments with wildlife-highway conflicts; (2) milepost-specific recommendations for potential wildlife crossings; (3) a benefit-cost analysis for the highest priority segments; and (4) a decision-support toolbox that includes best practices for integrating prioritized wildlife-highway segments into transportation planning and project development, or, in select cases, identifying potential stand-alone mitigation projects.

### 5.4.2 Mitigation Crediting

This project did not use mitigation credits to value wildlife crossings or other connectivity enhancements. However, the function-based and avoided cost metrics used for prioritizing wildlife connectivity on a regional basis are among the most useful metrics that state DOTs could use to quantify credits under a mitigation program for wildlife connectivity. The data available for analysis included current and predicted traffic volumes; 10 years of reported WVC accident report data; 10 years of WVC carcass data; GPS collar data from 10 studies of mule deer and five studies of elk; and seasonal habitat and migratory corridor mapping. The GPS collar data were used to develop models predicting the probability of mule deer and elk crossing highways but were not used to prioritize wildlife crossings because the models poorly predicted mule deer and elk habitat selection along highways. Alternatively, WVC risk was modeled for both mule deer and elk based on observed WVCs crash and carcass data (Kintsch et al. 2019).

Kintsch et al. (2019) also explored several additional prioritization criteria, which could foreseeably be used as metrics to value wildlife crossings or other connectivity enhancements focused on mitigating impacts from deer and elk collisions. These include the density of mule deer and elk herds in winter concentration areas along highways; the distance of mule deer and elk migration movements multiplied by herd sizes; the 5-year average annual WVC count as a proportion of mule deer and elk herd sizes; and the modeled connectivity value for other potential focal species, such as Canada lynx.

### 5.4.3 Lessons Learned

The West Slope Wildlife Prioritization Study is a good example of a state DOT completing step 5 of the IEF as it would relate to wildlife connectivity. The study demonstrates that the prioritization of wildlife connectivity mitigation is useful for identifying potential metrics that are informative for valuing wildlife crossings and other enhancements in the western United States. The study revealed that GPS collar data from studies of mule deer and elk in proximity to highways, but not focused on highway impacts, may not be predictive of their highway crossings. WVCs and accident report data were most informative for prioritizing mitigation and would be among the most useful metrics. Furthermore, the cost-benefit model identified locations where wildlife connectivity mitigation could generate the most value if the credits were to be based on the model results or its input parameters.

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# APPENDIX A

# LITERATURE REVIEW,

# SURVEY,

# AND PRACTITIONER INTERVIEW REPORT

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# 1.0 ONLINE SURVEY

## 1.1 ONLINE SURVEY METHODS

The purpose of the survey was to develop a national perspective on the state of the practice of wildlife connectivity mitigation in the United States. The survey sought to elicit information from experienced practitioners on how they were developing approaches, protocols, and requirements for wildlife connectivity mitigation. The information gathered from the survey was also to provide insight into the current use of mitigation credits for wildlife crossings and other connectivity enhancements recognized by a permitting authority, including which states or regions are actively using this or a similar approach to meet their mitigation needs for wildlife connectivity impacts, and if applicable, the valuation methods and metrics used. Because the literature review revealed limited information about valuation methods and crediting systems for wildlife connectivity mitigation, the survey was also developed to identify the most-experienced individuals willing to discuss their specific programs and projects in follow-up phone interviews.

An online national survey of key environmental staff at state DOTs and federal and state natural resource agencies was conducted using Qualtrics™ research software in April 2019. To maximize the response rate and to reduce the time demand on respondents, the questionnaire was limited to 26 questions. The participants were asked to respond within four weeks. After one week, the research team re-engaged each potential survey participant to confirm receipt of the survey and to inquire if the participant had any questions pertaining to the questionnaire, or if they required additional time to complete the survey. A final reminder was sent the last week of the survey.

Appendix A contains a copy of the interview questions. Note that for some questions, survey respondents could select multiple responses (i.e., questions 9, 11, 12, and 18), so the total percentages reported could exceed 100%. Also, survey respondents could skip any question that they were unable to answer, so the total percentages reported for some questions could be less than 100% of respondents.

## 1.2 ONLINE SURVEY RESULTS

### 1.2.1 Characteristics of Survey Respondents

A total of 1,035 individuals were invited to complete the online survey from which 234 respondents (23%) participated in the online survey. These individuals represented a variety of agencies and organizations: 54% were state transportation agency staff; 1 (0.6%) was federal transportation agency staff; 26% were state natural resource agency staff; 5% were federal natural resource agency staff; 3% were academic researchers; and 11% were affiliated with other organizations.

Of the 234 respondents, 168 identified the type of organization to which they belonged (Table 1). Unsurprisingly, the highest number of respondents were from state transportation agencies (91), and only one federal transportation agency member responded. There were more than 50 state and federal natural resource agency respondents.

Of the 19 respondents who described their organization as "other" (Table 1), six were private consultants, five were from non-profit organizations, two were from Metropolitan Planning Organizations, and the remaining six were single categories such as a tribal wildlife program officer, an attorney, or they did not categorize themselves.

There was broad representation from across the nation, with at least one respondent in every state except Alabama, Hawaii, Rhode Island and Tennessee (Figure 1). Three states had 10 or more respondents, California (20), Utah (11), and Idaho (10) (Figure 1). Seven states had between 5 to 9 respondents each, 31 of the states had 2 to 4 respondents, and five had one respondent, including the District of Columbia (Figure 1).

**Table 1. Agencies and corresponding number of respondents that participated in the online survey.**

| Organization Type | Number of Responses |
|---|---|
| Federal transportation agency | 1 |
| State transportation agency | 91 |
| Federal natural resource agency | 9 |
| State natural resource agency | 43 |
| Academic institution | 5 |
| Other | 19 |
| **Total** | **168** |

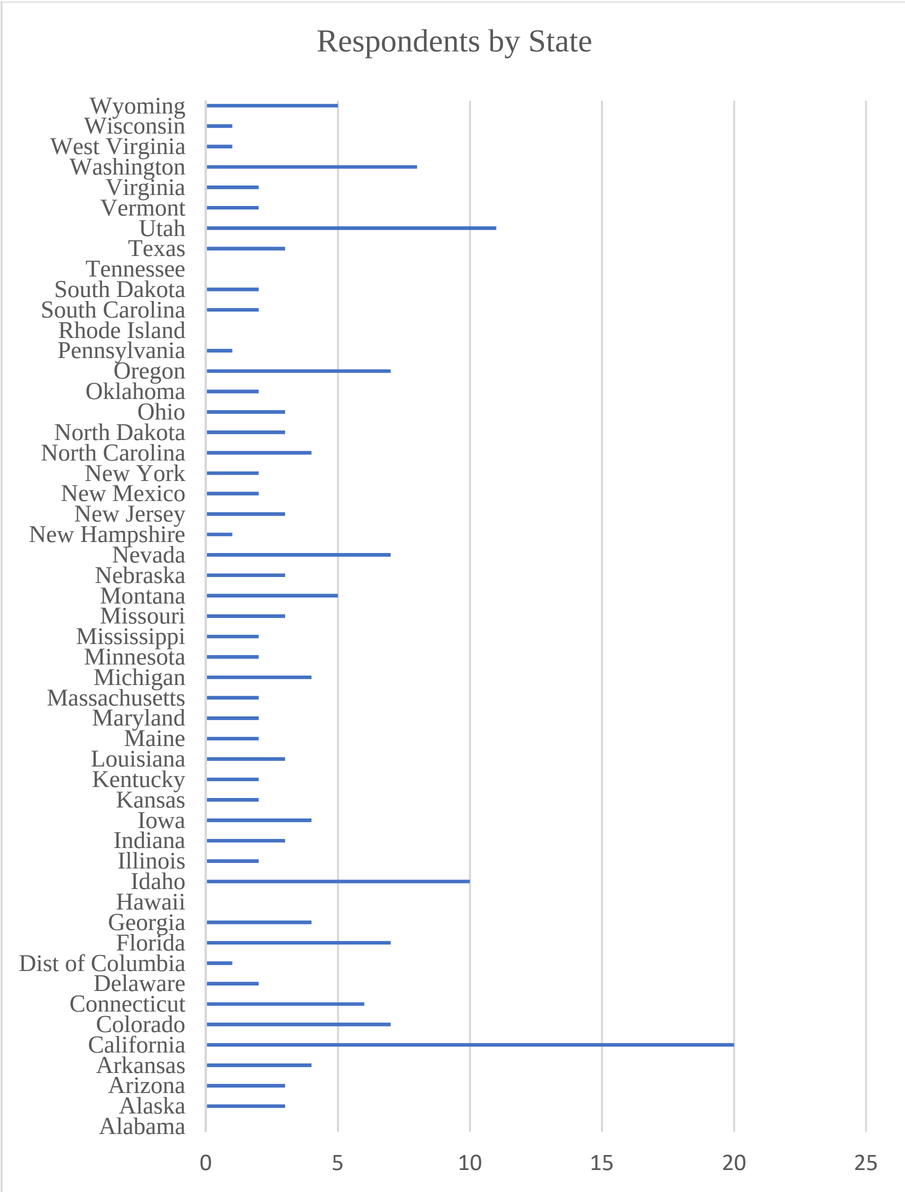


**Figure 1. Frequency of the respondents of the survey by state.**

Of the state transportation agencies in states with the highest number of wildlife crossings according to Bissonette and Cramer (2008)—Florida, Arizona, Montana, California, and Massachusetts—all five states had representatives responding to the survey.

Respondents with the primary job title or role as wildlife biologists (31.5%) and environmental specialists (20%), together, comprised more than 50% of the respondents to the survey (Figure 2). Of the 13.3% of the respondents who chose "other" to describe their position, the variety of position descriptions ranged from resident engineer to geomorphologist to asset manager.

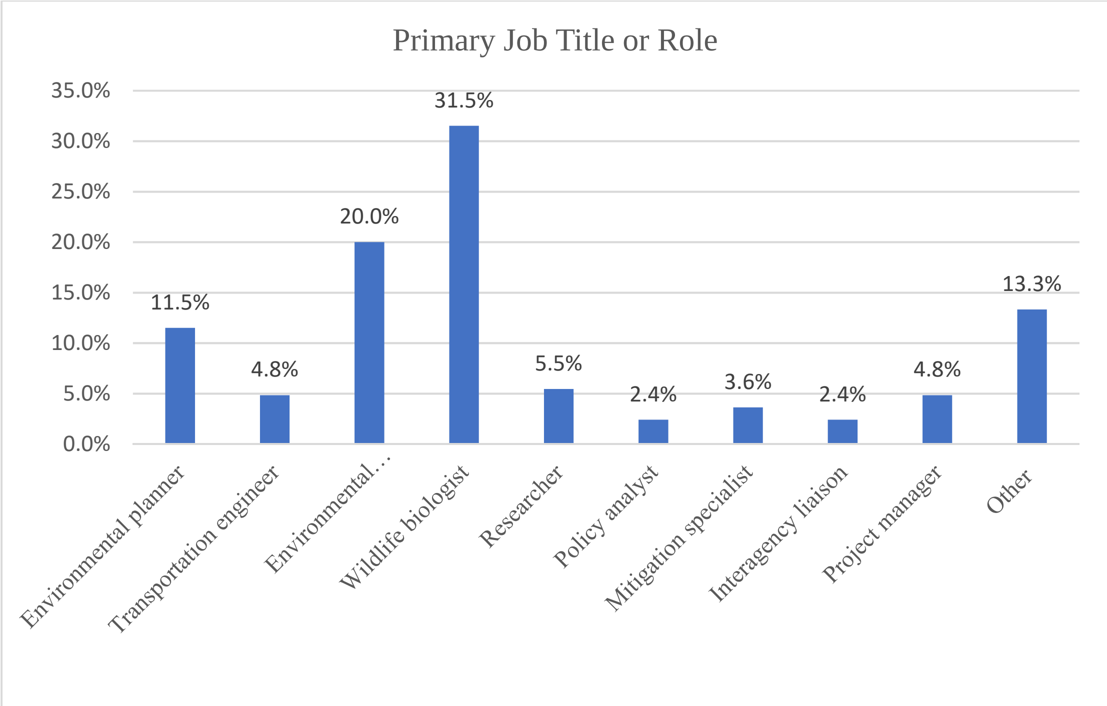


**Figure 2. Primary job title or role of respondents.**

A large majority of the survey respondents, more than 90%, have worked on wildlife connectivity projects related to transportation (Figure 3).

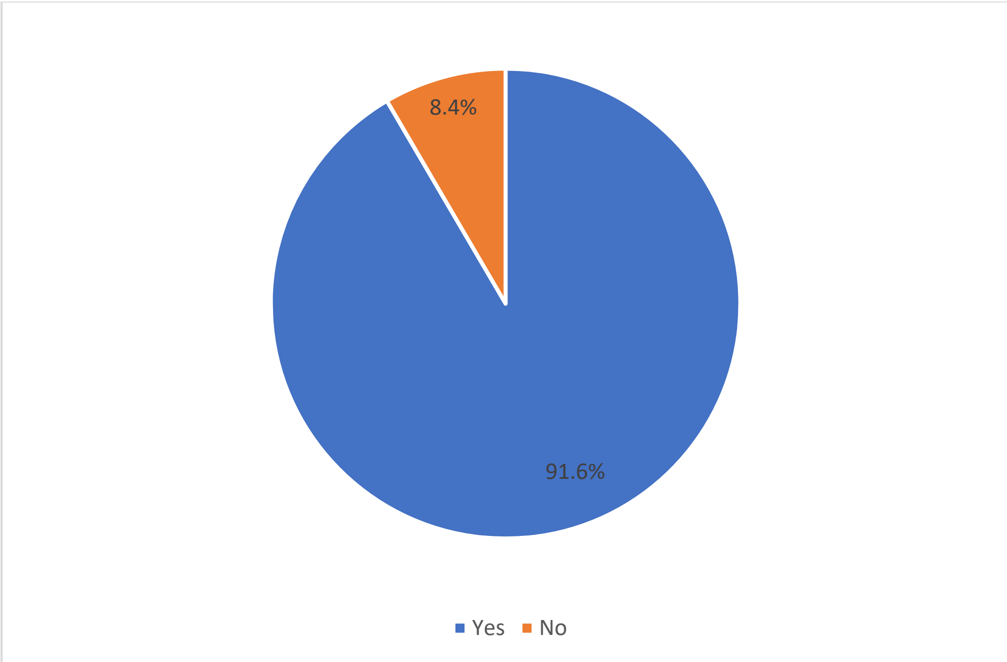


**Figure 3. Percent of survey respondents that have engaged in transportation-related wildlife connectivity projects.**

### 1.2.2 States Incorporating Wildlife Connectivity Early in the Transportation Planning Process

To identify the states where wildlife connectivity is an important consideration during transportation project development, we asked the following question:

- "Does your state ever incorporate wildlife connectivity assessment and mitigation needs early in the transportation project programming, planning, and design process?"

The respondents, to a large degree (84%), confirmed their state incorporates wildlife connectivity assessment and mitigation considerations early in the programming, planning, and project design processes (Figure 4).

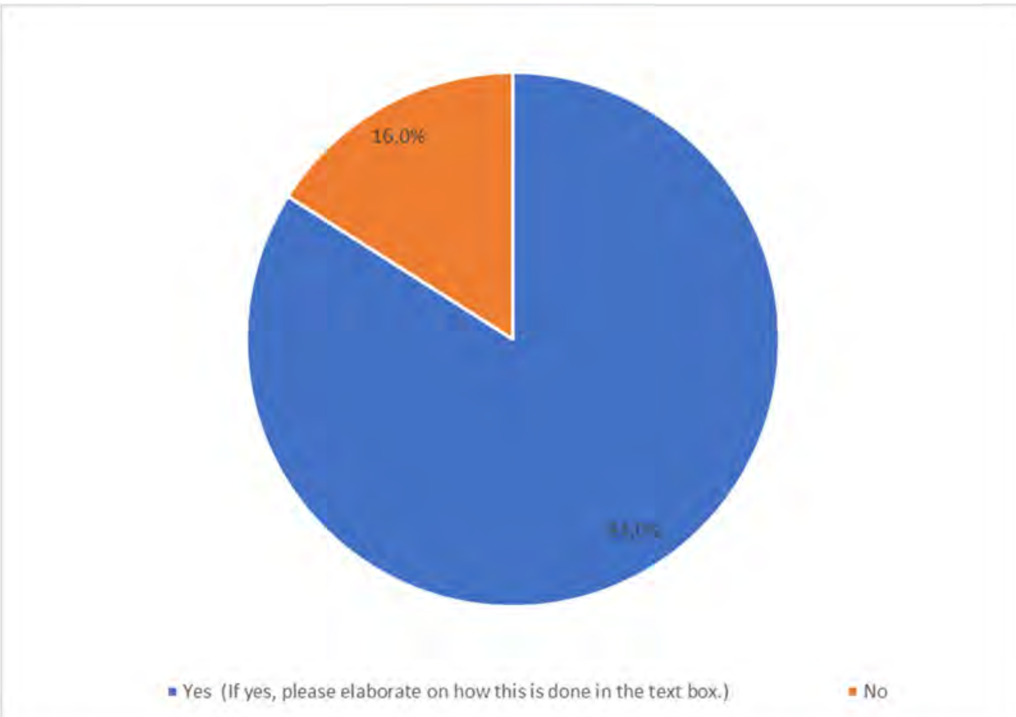


**Figure 4. Percent of survey respondents that agree their state incorporates wildlife connectivity assessments and mitigation needs early in the programming, planning and project processes.**

If the respondents answered yes, they were asked to explain the methods that are used to consider the needs of wildlife connectivity in the transportation processes of their state.

Examples of responses include:

- "We engage agencies and wildlife interest groups early to solicit their input and knowledge" (North Carolina).
- "We work with state game agency and other stakeholders." Also, utilize a recent process of statewide priority projects that was developed through an agency—NGO collaborative effort (Wyoming).

At the project level, wildlife connectivity mitigation is typically considered collaboratively during the environmental review process, usually involving state DOTs engaging with their state natural resource agencies. When federally listed threatened or endangered species could be impacted, USFWS is consulted. In several states, respondents said that wildlife advocacy groups were also included in pre-project planning efforts involving wildlife connectivity assessments or evaluations of mitigation needs.

The CDFW gave examples of the types of plans or connectivity analyses it uses to inform long-term transportation plans, programs, and projects: California Essential Habitat Connectivity Project, Natural Community Conservation Plans, and RCIS, as well as county-level plans.

Respondents suggested that their state DOTs typically consider wildlife connectivity mitigation for projects on a case-by-case basis, typically for the following reasons:

(1) project impacts to threatened and endangered species;

(2) project impacts to aquatic habitat connectivity;

(3) statewide multispecies connectivity analyses:

For example, in southern California, they consult the South Coast Missing Linkages Project (created by the NGO South Coast Wildlands), which shows wildlife connectivity within the region and prioritizes linkages. In addition, they use the California Essential Habitat Connectivity Project, which also shows areas that are essential for wildlife connectivity throughout California. California also uses information from the Habitat Connectivity & Wildlife Corridor Overlay Zone and associated ordinances from Ventura County as well as the Los Angeles County Significant Ecological Areas Program. They also use data from wildlife movement studies conducted by the National Park Service. All information gathered from these various conservation plans is used when doing a biological analysis during the project identification phase and the natural environment study during the project approval and environmental document phase;

(4) research project findings about animal movements;

(5) known WVC hotspots; and

(6) state initiatives focused on big game migration routes.

Respondents from the following states replied “no,” their state does not incorporate wildlife connectivity assessment and mitigation needs early in the transportation project programming, planning, and design process: Kentucky, Ohio, and Indiana.

The survey sought to identify the relative experience that the respondents had in conducting wildlife connectivity mitigation and the type of framework or regulatory requirements they followed to implement such mitigation, and to elicit which types of wildlife connectivity and focal species groups (large carnivores, ungulates, small mammals, reptiles, and aquatic fauna) the respondents have experience with.

Most survey respondents, over 91%, noted that they have already worked on wildlife connectivity mitigation projects. Just over one-quarter of the respondents, 25.2%, have worked on more than 10 projects, representing a cadre of seasoned experts in the survey (Figure 5).

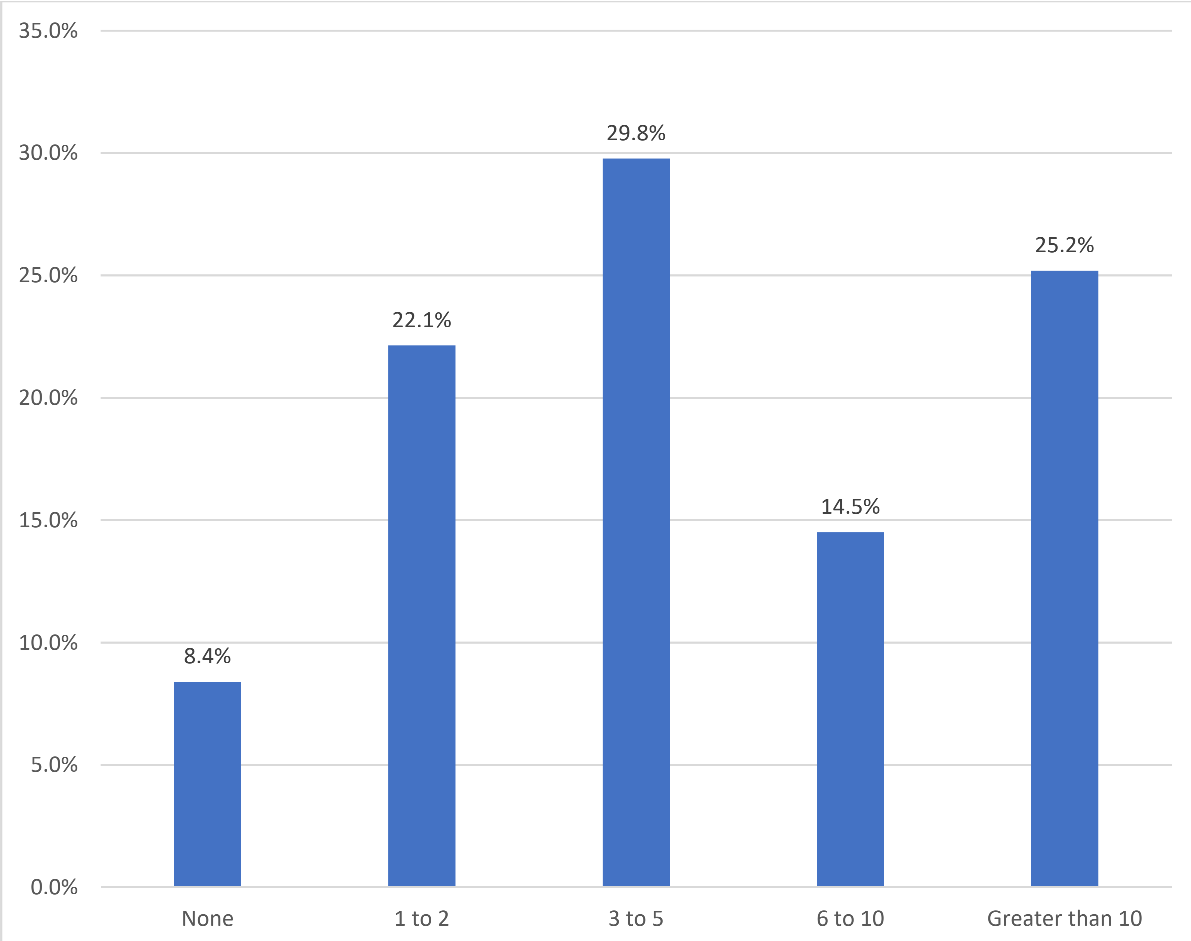


**Figure 5. Number of wildlife projects worked on by survey respondents.**

### 1.2.3 Stakeholder Agreement(s) to Preserve or Enhance Wildlife Connectivity

One rationale for incorporating wildlife connectivity considerations into transportation projects may be related to state DOT stakeholder agreements (see Figure 6). Furthermore, stakeholder agreements would be necessary for the development of wildlife connectivity mitigation crediting program. A total of 59.8% of survey respondents said that their state DOT had such agreements to preserve or enhance connectivity in, or adjacent to, their right-of-ways (ROWs).

Stakeholder agreements to preserve or enhance wildlife connectivity included the following examples:

- Since 1980, CDOT has had a Memorandum of Understanding (MOU) with the Department of Natural Resources, Division of Wildlife for managing wildlife within highway ROWs. This MOU is being updated in 2019 to focus on data sharing and interagency cooperation to improve highway design to benefit wildlife and habitat connectivity. Recently, to enhance habitat connectivity and reduce WVCs associated with the Interstate I-70 Mountain Corridor project, an interagency committee known as “A Landscape-Level Inventory of Valued Ecosystem Components” (ALIVE)” was formed (CDOT et al. 2008). The ALIVE committee identified 13 areas potentially limiting wildlife migration (including elk, mule deer, bighorn sheep, and Canada lynx), referred to as linkage interference zones, and recommended mitigation actions that included enhancing existing or creating new wildlife crossing structures. An MOU between CDOT, Colorado Parks and Wildlife, USFWS, U.S. Bureau of Land Management, and FHWA, signed in April 2008, details the responsibilities of each agency and outlines areas where wildlife connectivity should be preserved or enhanced.

- In Wyoming, a respondent described that “There are MOUs with the Wyoming Game and Fish Department on signing, and sometimes other mitigation tactics. Wyoming DOT is in the process of working with the stakeholders to allow the stakeholders to possibly perform some mitigation work.”
- In Idaho, a respondent referenced an MOU between the Idaho DOT and Idaho Department of Fish and Game for improved collaboration for reducing highway impacts on wildlife. Both agencies agree to share roadkill data, and the Idaho Department of Fish and Game will use roadkill data to map and prioritize wildlife crossings, linkages, and public safety concerns. The Idaho Department of Fish and Game will also develop collaborative highway treatment plans and funding to reduce road kill, increase wildlife linkage/connectivity/corridors, and reduce hazards to drivers. Both parties will meet annually to discuss issues of mutual concern, including: (1) opportunities for wildlife crossing improvements and inclusion with current highway construction projects, and (2) evaluating joint funding sources for wildlife crossings.
- Caltrans has MOUs with various entities. Some are site-specific, while others cover a wider geographic area.
- VTrans has an Memorandum of Agreement (MOA) with the Vermont Fish & Wildlife Department to collaborate and enhance wildlife connectivity and habitat in regular projects whenever practicable.
- In Colorado, there are a few stakeholder agreements within the state, in particular one focused on its I-70 Mountain Corridor Project. This MOU, which includes multiple agencies, helps to include landscape-level planning for wildlife connectivity.
- Massachusetts DOT has Agreements with the Massachusetts Division of Fisheries and Wildlife; Massachusetts Department of Environmental Protection, and USACE.
- The Alaska DOT and Fish and Game have an MOU to “establish a Wildlife Working Group as means for identifying cost-effective programmatic approaches affecting both wildlife safety and wildlife sustainability” (State of Alaska 2013).

#### 1.2.4 Regulatory Mechanisms for Wildlife Connectivity Mitigation

In addition to stakeholder agreements, there may be regulatory mechanisms that state DOTs must follow when they consider wildlife connectivity mitigation. A total of 62.3% of survey respondents responded yes when asked: "Are there any regulatory mechanisms in your state under which wildlife crossing structures or wildlife connectivity enhancements have been or could be required to mitigate for transportation-related impacts to wildlife connectivity?".

When asked to describe such regulatory mechanisms, it was unanimous that state DOTs had to follow the requirements of the federal ESA and Clean Water Act. In addition, wildlife connectivity mitigation actions could be required under state statutes, including the California, Nebraska, and Massachusetts

ESAs, and the CEQA. Also, New Jersey has a Flood Hazard Control Act that was identified, as was New York's Adirondack Park Travel Corridors Unit Management Plan.

When asked to identify potential regulatory triggers that could require wildlife connectivity mitigation in their state, the survey respondents' largest response was ESA compliance (41%), followed by highway safety (35%) (Figure 6).

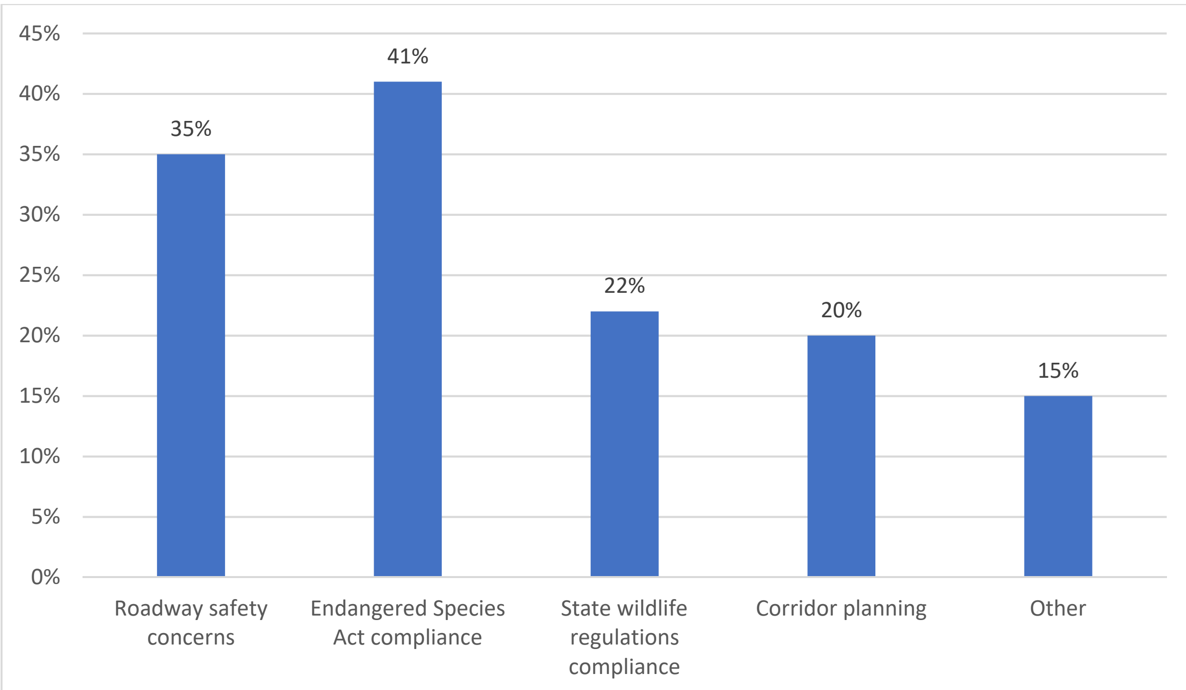


**Figure 6. Response rates that identified potential regulatory triggers for wildlife crossing structures or other connectivity enhancements that could be required by their state.**

When respondents were asked to identify other regulatory triggers (Figure 6) that might require wildlife crossings or other connectivity mitigation, they suggested such things as the Clean Water Act, Fish and Wildlife Coordination Act, municipal and regional long-term transportation plans, and Federal Land Management Agency resource management plans.

For example, the I-90 Snoqualmie Pass Project, East Hyak to Easton, is located in an area recognized as a critical connective link to the north-south movement of species between relatively undeveloped U.S. Forest Service (USFS) land in the Cascade Range. This project setting led FHWA and Washington State DOT to include ecological connectivity as part of the project’s purpose and need (online at: https://www.wsdot.wa.gov/sites/default/files/2019/03/06/chapter-1-eis-i-90-project.pdf [accessed June 20,2019]).

The survey sought to identify the types of wildlife connectivity mitigation measures that were deployed as a result of following a regulatory framework. There was no clear favorite measure deployed as a result of regulations, although many of the responses were for structural mitigation measures (Figure 7).

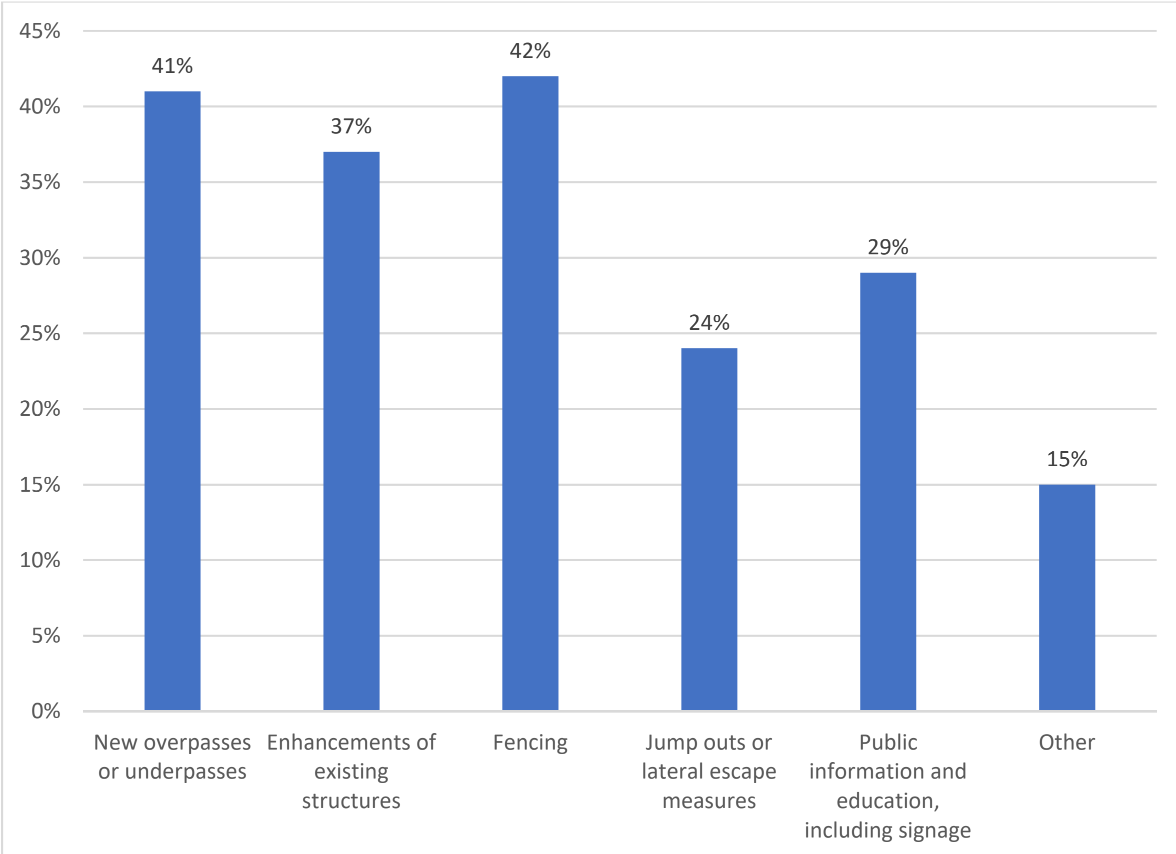


**Figure 7. The types of wildlife connectivity mitigation respondents have experience in implementing under a regulatory framework.**

Figure 7 shows many other mitigation measures used as a result of regulations under the "other" category, such as: animal detection systems, cattle guards on private easements, culverts, bridges, fish passage, habitat management, removing fencing, fixing mitigation fencing, and landscaping for pollinators.

Respondents were queried, based on their experience, which types of regulatory frameworks led to the implementation of wildlife crossing structures. The most cited law was the ESA, 23 times, and that was followed by requirements under NEPA, at 18 times (Figure 8). If they responded "other" they were asked to identify the regulatory framework. Responses to "other" included such laws, policies or regulations as 2014 Presidential Memorandum on Pollinators, Fish and Wildlife Coordination Act, a Tribal MOA, and USFS plans.

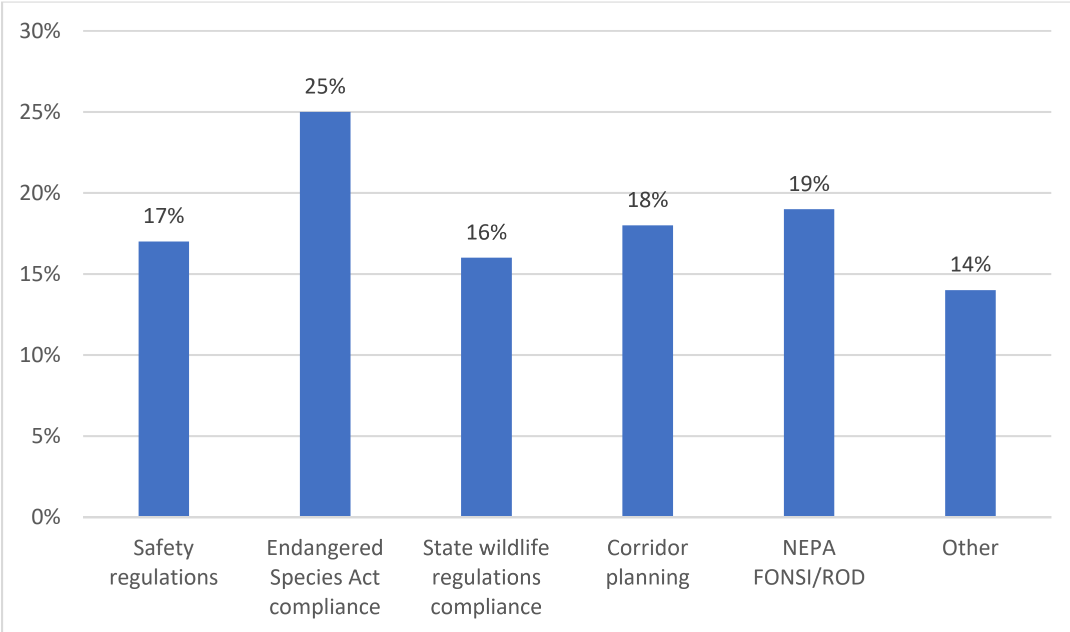


**Figure 8. Identification of the regulatory framework by survey respondents that led to the implementation of wildlife crossing structures in their state.**

#### 1.2.5 Funding Sources for Wildlife Connectivity Mitigation

The survey sought to determine who funded wildlife connectivity mitigation projects and relatedly, who funded mitigation credits. Survey respondents identified that the most common sources of funding were federal (40%) and state DOT (38%) sources (Figure 9). The types of federal sources of funding identified by the respondents were a variety of FHWA programs, environmental agencies, USFWS, and USFS. State sources of funding included general funds, DOT funds, gas tax, ROW funds, trust funds, state planning and research funds and state legislatively allocated funds. Non-profit organizations were the third highest mentioned source of funding (15%) and respondents listed many different national to local wildlife, sporting, and conservation organizations. A total of 14% of the respondents identified state wildlife agencies as a funding source (Figure 9) and mentioned many different programs, depending on the state.

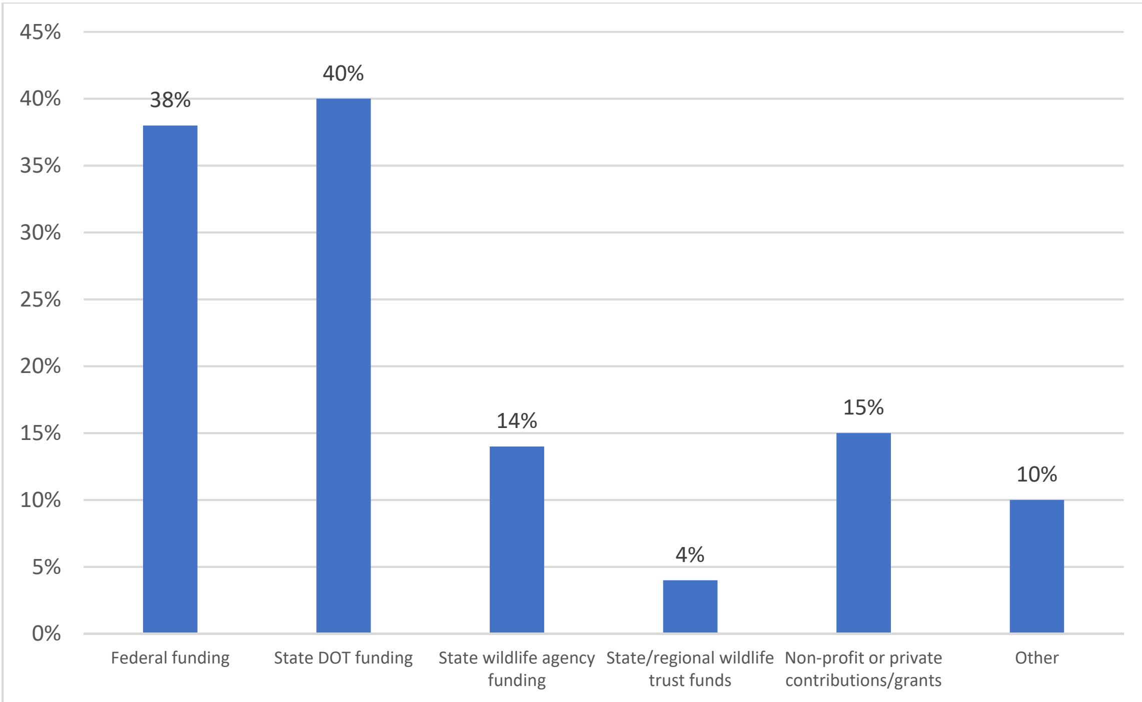


**Figure 9. The sources of funding identified in the survey that pay for wildlife connectivity mitigation measures, such as wildlife crossing infrastructure.**

### 1.2.6 Funding Sources for Mitigation Credits

The primary sources of funding for mitigation credits (e.g., wetlands mitigation banking and conservation banking credits) were identified by survey participants; the two most often selected sources were federal, 14% and state DOTs, 12% (Figure 10). When asked to specify federal sources, most often it was the FHWA (FWHA) and environmental agencies. For the state DOTs, sources identified were the project's funds, general funds, and the State Transportation Improvement Program. One source for private funds that was mentioned several times was road infrastructure agency/concessionaire. Several respondents mentioned that their state does not yet have a program for credits.

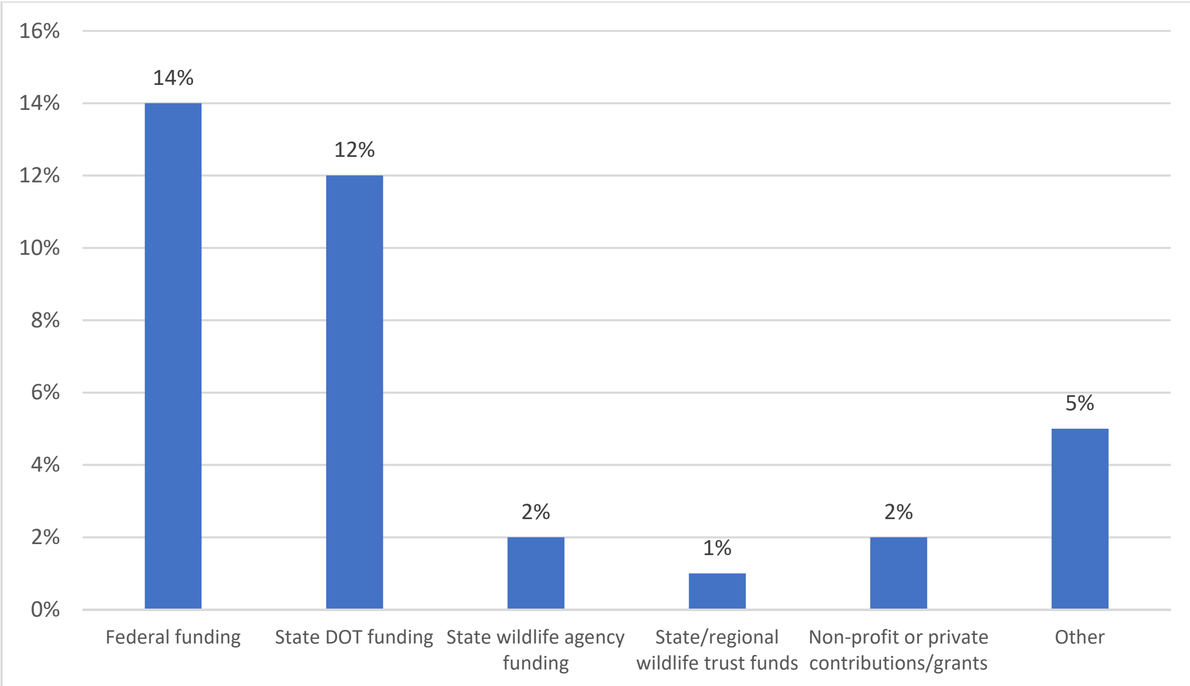


**Figure 10. Percent of the respondents to the survey who listed each category as a primary source of funding for wildlife connectivity mitigation credits.**

Many respondents suggested that the availability of funding for wildlife crossings often dictates the level of consideration for incorporating wildlife connectivity when planning transportation projects.

### 1.2.7 Focal Species for Wildlife Connectivity Mitigation

The survey sought to identify which groups of taxa were the focus of existing wildlife connectivity mitigation by state DOTs. The taxonomic groups in the survey were separated into large carnivores, ungulates (hoofed animals), small mammals, reptiles, amphibians and aquatic species. Respondents who did not know if their state had mitigation projects for each group varied between 27.5% for large carnivores (Figure 11) to 36.6% for amphibians (Figure 15). Respondents who noted that there were zero projects in their state for a particular taxonomic group ranged from a low of 10.8% for aquatic fauna (Figure 16) to a high of 36.6% for amphibians (Figure 15). Conversely, 33.8% of the respondents estimated their state had 10 or more wildlife connectivity mitigation projects for aquatic fauna (Figure 16); only 7.6% estimated they had 10 or more mitigation projects for amphibians (Figure 15).

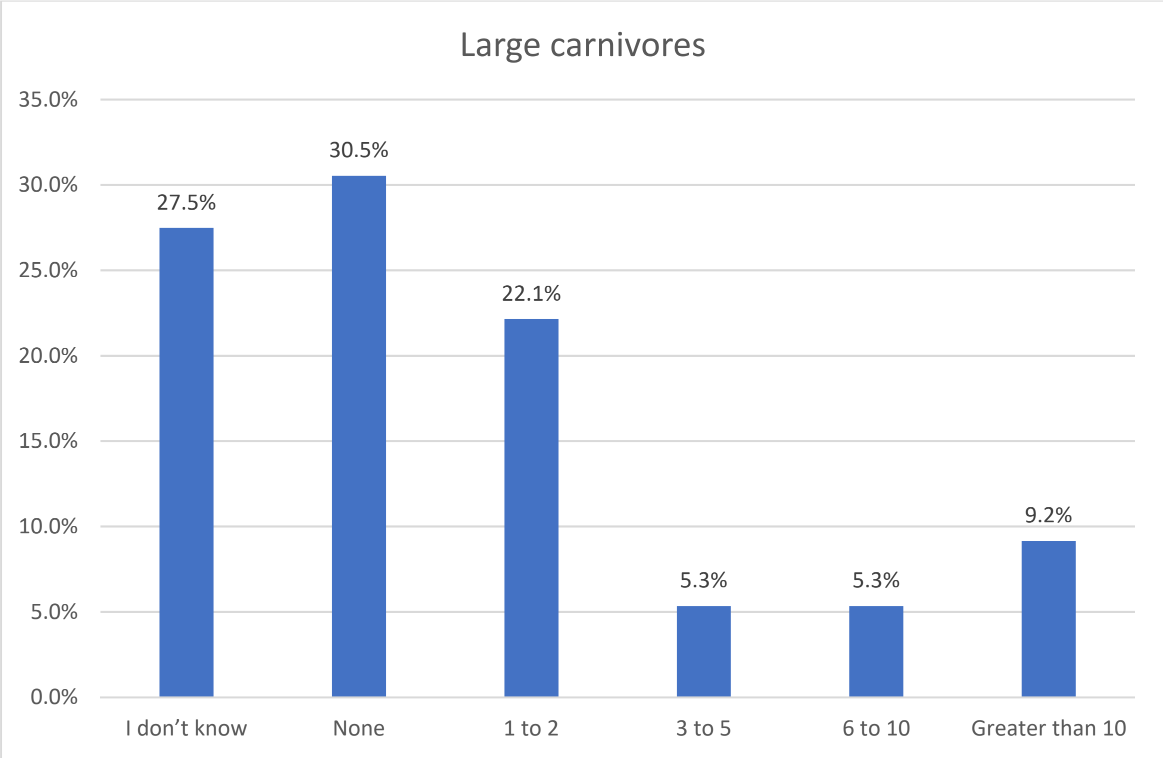


**Figure 11. Estimated number of large carnivore connectivity mitigation projects in respondent's state.**

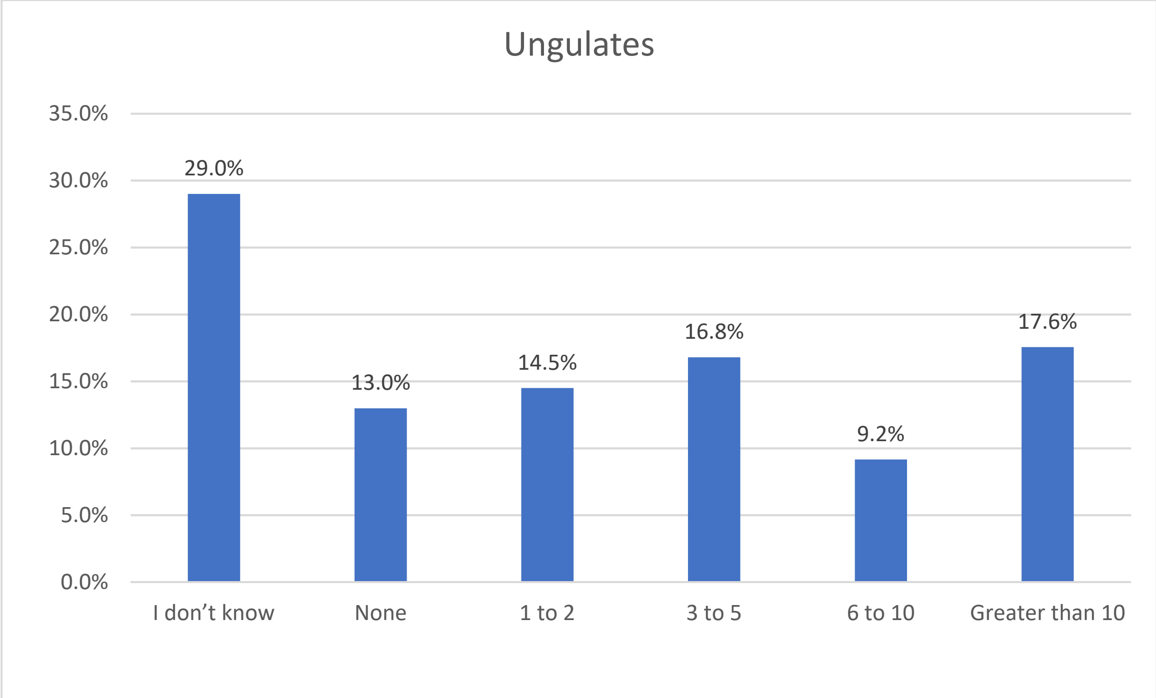


**Figure 12. Estimated number of ungulate (hoofed animals) connectivity mitigation projects in respondent's state.**

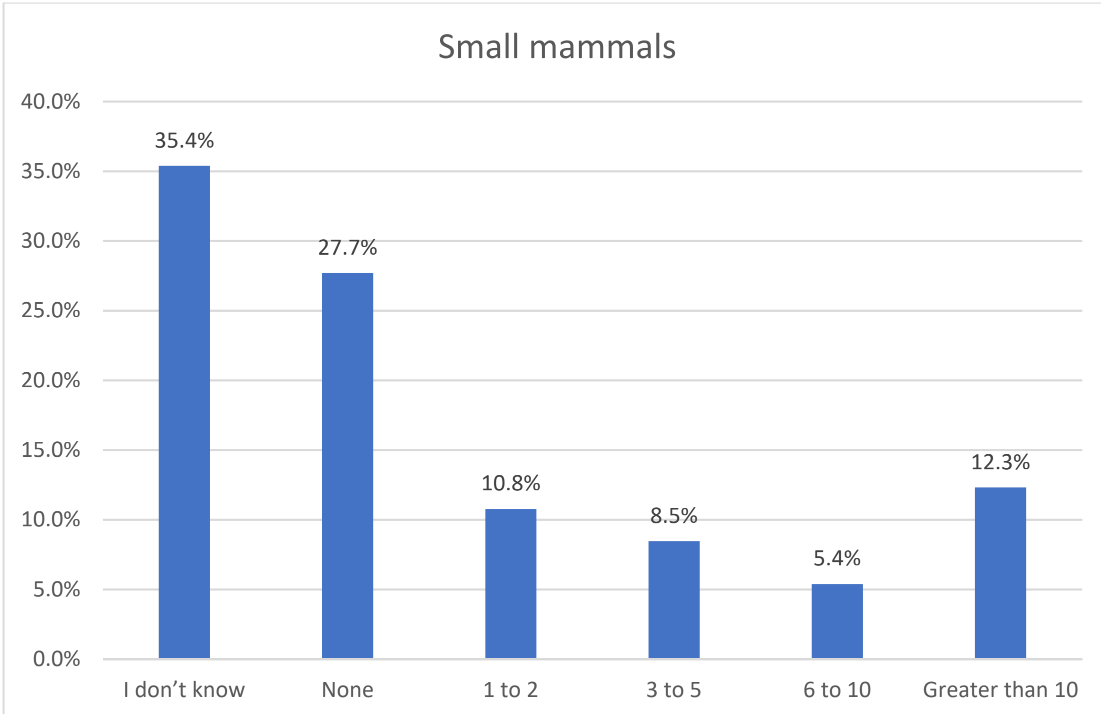


**Figure 13. Estimated number of small mammals (smaller than a coyote) connectivity mitigation projects in respondent's state.**

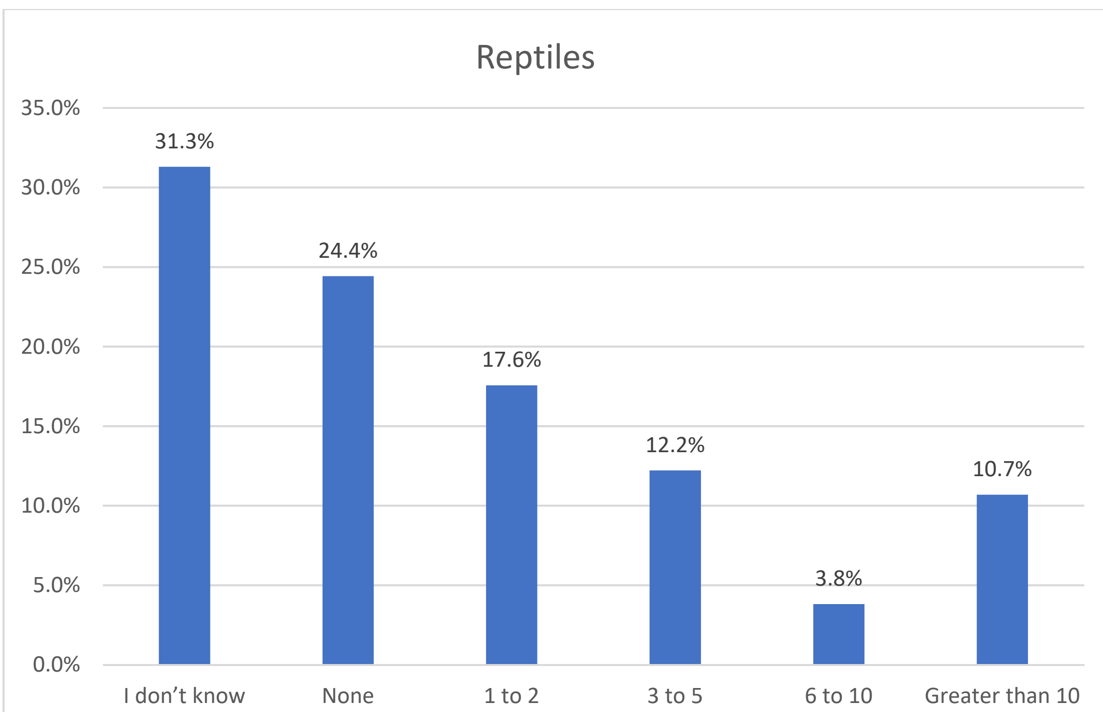


**Figure 14. Estimated number of large carnivore connectivity mitigation projects in respondent's state.**

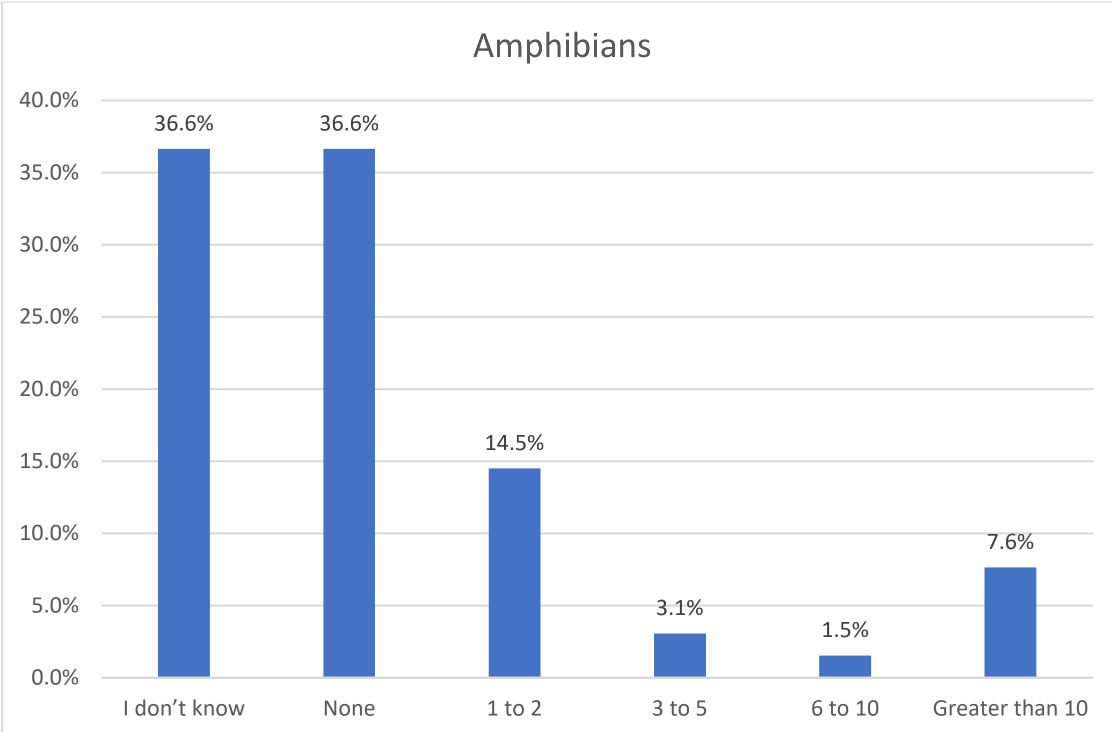


**Figure 15. Estimated number of amphibian connectivity mitigation projects in respondent's state.**

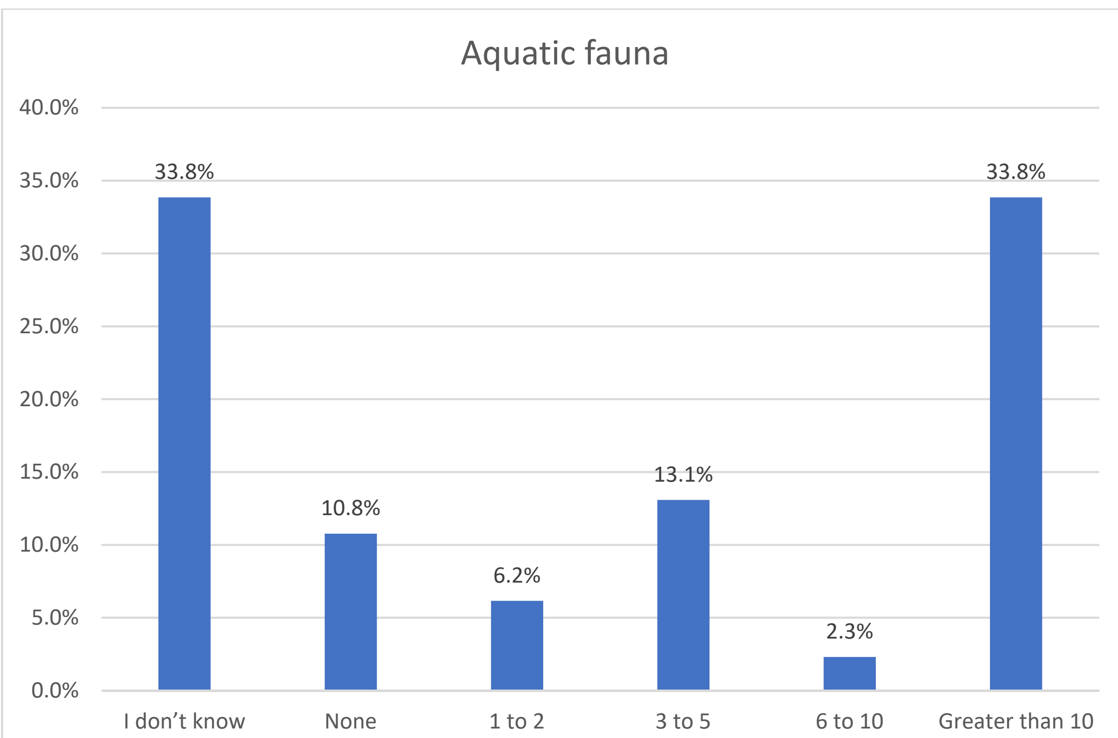


**Figure 16. Estimated number of aquatic fauna connectivity mitigation projects in respondent's state.**

### 1.2.8 Availability of Mitigation Credits to Offset Wildlife Connectivity Impacts

For the various taxonomic groups that were the focus of connectivity mitigation projects (Figures 11 thru Figure 16), respondents were asked if there were credits available in various banking programs to provide for the mitigation. The responses were overwhelmingly no (91.9%). The yes responses (8.9%) indicate few of the current wildlife connectivity mitigation projects that have occurred to date across the nation are part of mitigation banking programs. The respondents who answered yes were asked to recognize specific programs, and they identified such in-lieu fee programs for bats and Canada lynx and a mitigation bank for Florida panther. Each of these species are threatened or endangered under the ESA.

### 1.2.9 Wildlife Connectivity Mitigation Covered by Habitat Conservation Plans

HCPs are required under the ESA for private entities seeking an application for an incidental take permit for projects that might result in the destruction of a threatened or endangered species. When asked whether connectivity impacts of a transportation project in their state were covered under a HCP, 75.7% responded no. Those that responded yes (24.3%) were asked for more specifics and they identified a variety of HCPs for various species such as desert tortoises, Karner blue butterfly and Florida panther. They also identified a variety of HCPs for different geographies such as San Diego County Multispecies HCP (CA), Clark County Multispecies HCP (NV) and Eastern Collier County Multiple Species HCP (FL).

### 1.2.10 Out-of-kind Mitigation to Offset Wildlife Connectivity Impacts

Respondents were asked about the wildlife connectivity mitigation projects they worked on and whether the mitigation actions of that project were used to offset wildlife connectivity mitigation for other, separate transportation projects. Over 66% said no, 21.3 % responded they had not worked on mitigation connectivity projects and 12.3% responded yes (Figure 17).

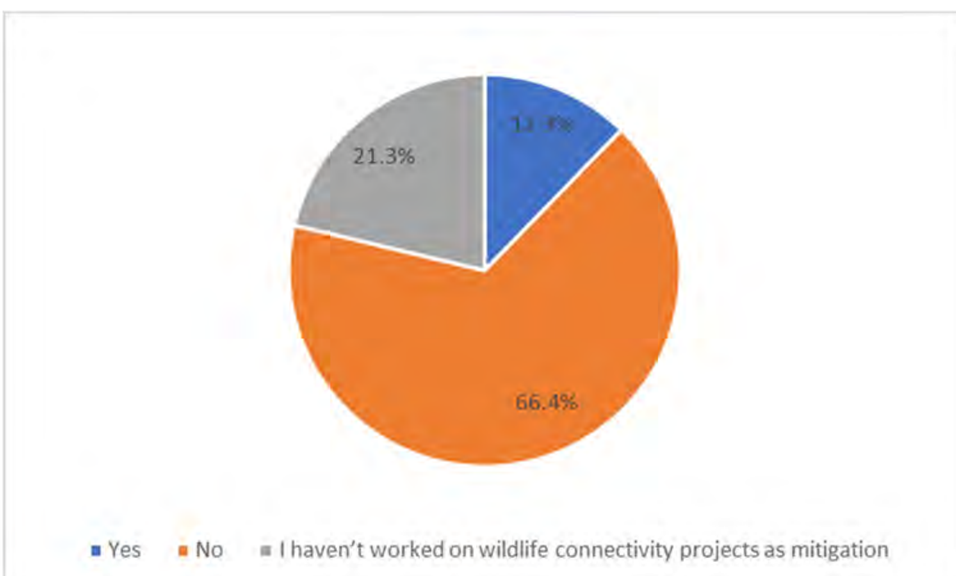


**Figure 17. Responses to the question of whether wildlife connectivity mitigation from one transportation project the respondents worked on was used to offset wildlife connectivity mitigation needed for another separate transportation project.**

The survey sought to identify whether wildlife connectivity mitigation projects were used for impacts to wildlife connectivity by the project itself (self-mitigation) or as mitigation for another transportation project's impacts to wildlife connectivity (out-of-kind mitigation) (Figure 18). Most survey participants responded yes (47.5%) meaning it was for either in- or out-of-kind mitigation. Fewer answered no (31.5%) and 21.3% indicated they hadn’t worked on a mitigation project for wildlife connectivity.

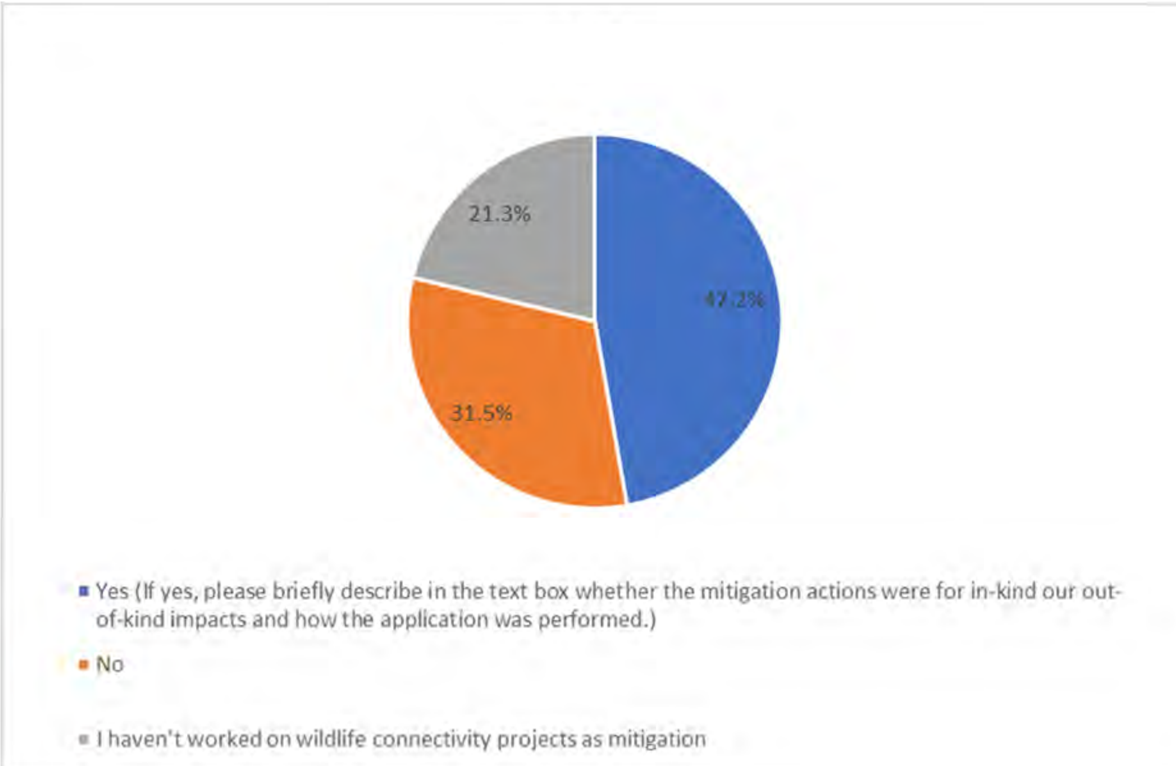


**Figure 18. Response rates of survey participants when asked whether wildlife connectivity mitigation projects they worked on were used for impacts to wildlife connectivity by the project itself (in-kind mitigation) or for mitigation actions that were used for another transportation project's impacts to wildlife connectivity (out-of-kind mitigation).**

A variety of examples were given by participants who responded yes to self- or out-of-kind mitigation for wildlife connectivity. Self- mitigation actions included building crossing structures for fencing that reduced WVCs, building tunnels for small animals, constructing fences and crossings due to the highway's severance of habitat connectivity, building crossings to mitigate the highway's barrier effect on ungulates, carnivores, reptiles and a variety of other taxa. It also included expanding existing culverts to improve wildlife passage.

In Nevada, a respondent suggested that “[a]ll of our large mammal projects have been to self-mitigate transportation projects and increase driver safety. Some were put in place because we included them within the NEPA documents, or done after the fact, due to safety concerns and partnerships with the wildlife agencies.”

Examples of out-of-kind mitigation for wildlife connectivity were for culverts that were installed for wildlife that also allowed for fish passage to rectify past transportation projects' impacts on fish passage in Idaho, mitigation packages were developed for the loss of habitat for the San Joaquin kit fox in California, and mitigation credits were accumulated by Maryland DOT by participating in the Bloede

Dam removal. In Maryland, the credits were based, in part, on protected streams and streams opened up for fish spawning.

#### 1.2.11 Permittee Required Mitigation for Wildlife Connectivity Mitigation

All of the survey participants were asked if they were "…aware of any recent, ongoing, or planned transportation projects that seek to mitigate wildlife connectivity impacts, through permittee-responsible mitigation, using a crediting process or valuation methodology?" Not all responded to this question, 34% indicated no and a mere 3% answered with a yes. One example given, was the California High Speed Rail Project that would need to address wildlife connectivity.

For those answering yes, they were asked how credits were calculated. The calculations were based on compensatory stream mitigation credits in Wyoming when they removed a dam. Two other respondents indicated the UMAM was used for wetlands mitigation.

#### 1.2.12 Advance Mitigation for Wildlife Connectivity Mitigation

Advance mitigation programs allow a state DOT to implement conservation actions that generate credits based on mitigation actions that provide ecological gain or environmental benefit to offset the predicted impacts of future transportation projects (e.g., see Caltrans' Advance Mitigation Program, online at: http://www.dot.ca.gov/env/advancemitigation/). When survey participants were asked if they had been involved in establishing advance mitigation in their state, 10.9% checked yes. The respondents were from California, Colorado, and Florida.

Survey respondents described Caltrans' Advance Mitigation Program, which allows for wildlife crossing structures to qualify as enhancement actions that can generate mitigation credits when a Resource Conservation Investment Strategy (RCIS) has been developed per Fish and Game Code §§ 1850 – 1861. The CDFW suggested that California can also potentially use a RCIS to evaluate habitat connectivity for focal species and identify wildlife linkages where wildlife connectivity could be maintained or enhanced.

#### 1.2.13 In-lieu Fee Programs for Wildlife Connectivity Mitigation

In-lieu fee programs allow DOTs to set aside funding for offsite mitigation, which for certain focal species, included funding for wildlife crossing projects. Thus, the method used to calculate the amount of contribution required for a given transportation project could provide insight into potential methods used to generate mitigation credits for wildlife crossings. To understand how in-lieu programs have been used to address wildlife connectivity, survey participants were asked if their state had any in-lieu fee mitigation programs that could provide for wildlife crossings or other enhancements. A total of 5% of the respondents said yes. The only reported in-lieu fee program that addresses wildlife connectivity is for Canada lynx in western Colorado, administered by CDOT. Other in-lieu fee programs mentioned by survey participants would not likely be used for wildlife connectivity mitigation, including Vermont's program managed by Ducks Unlimited for wetlands to upland habitats and a Range-wide Indiana Bat In-lieu Fee Program Instrument. New Jersey is making its new in-lieu fee program operational, so had nothing to report at the time of the survey.

#### 1.2.14 Quantitative Methods to Evaluate Improved Permeability from Wildlife Connectivity Mitigation Actions

The survey sought to determine the frequency that quantitative methods were used to determine the location and effectiveness of wildlife connectivity mitigation actions. When survey participants were asked if the projects that they worked on were located due to quantitative methods, over 43% responded yes, 37.8% no, and the remaining 18.9% hadn't worked on wildlife connectivity mitigation projects (Figure 19).

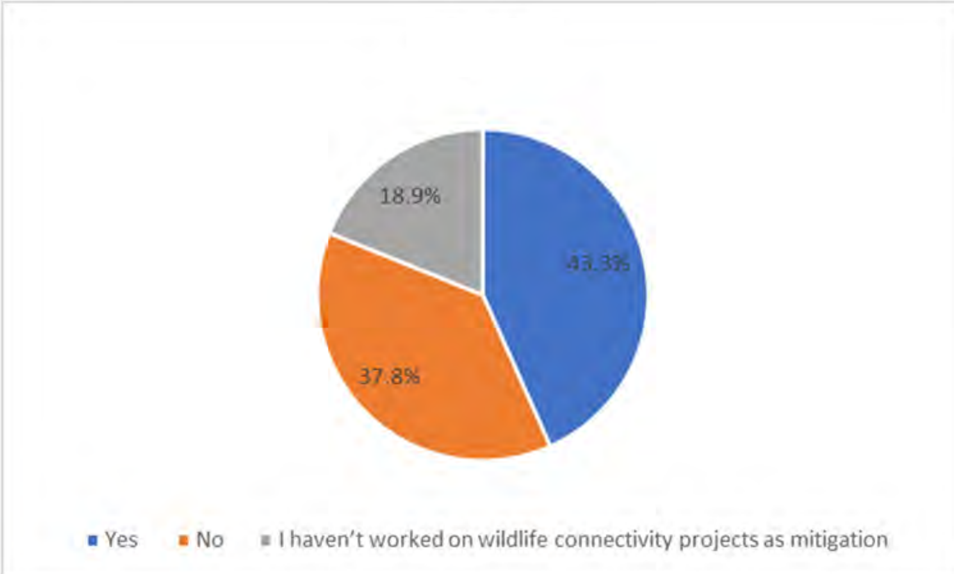


**Figure 19. Responses to the question, "for the wildlife connectivity mitigation projects you worked on, was the enhancement to improve permeability at a particular location determined quantitatively?"**

Those who indicated that they did use quantitative methods to determine wildlife connectivity mitigation locations used the following data: accident data and analyses, research project or study results in the area of the project, wildlife telemetry data, wildlife monitoring data, wildlife tracking data, pitfall traps, and camera trap photos. The types of data analyses that were used included GIS models, Brownian bridge models using GPS data for ungulates, roadkill surveys, and habitat evaluations.

#### 1.2.15 Level of Interest in Generating Mitigation Credits from Wildlife Connectivity Projects

Survey participants were asked if their state provided opportunities to generate credits for wildlife connectivity projects, would they employ that option. Nearly half, 42%, responded yes, 52% chose "maybe," while 6% selected no (Figure 20). For those answering yes, they gave a variety of reasons for why they would use an option to generate mitigation credits for wildlife connectivity projects if their state had such opportunities. Some were due to the benefits and incentives mitigation credits would provide for DOTs, wildlife populations, and society in general. Several respondents surmised that credit programs would create financial incentives for state DOTs to fund mitigation actions, provide flexibility on the best mitigation location, so it did not need to be in the existing transportation project's footprint, allow for the restoration of lost connectivity and would be useful for situations where providing mitigation is cost prohibitive. Several respondents said their state was actively exploring or developing such a mitigation program.

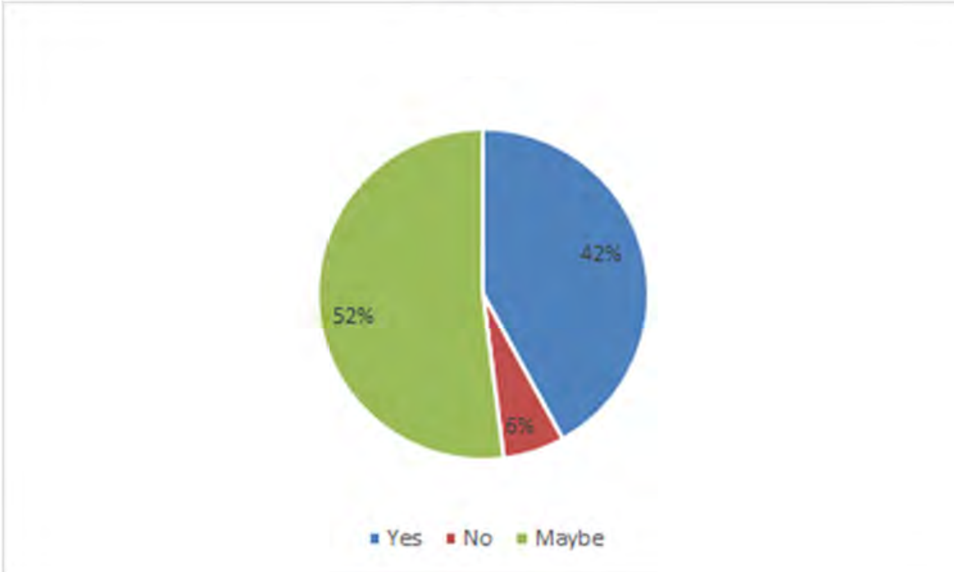


**Figure 20. Responses to whether the survey participant would employ an opportunity to generate mitigation credits from wildlife connectivity projects if their state had the option.**

For the 9.3% who responded no (Figure 20), their rationale for not employing a mitigation option for wildlife connectivity was that it was not a realistic or practical tool; their state only had very localized needs for wildlife connectivity mitigation; or that, since there were no regulations requiring connectivity, a banking program, like what is used for wetlands, would not be needed for wildlife connectivity.

#### 1.2.16 Methods and Protocols to Calculate Mitigation Credits

Over 12% of survey participants responded yes when they were asked if they had used methods or protocols to determine mitigation credits or values. Of those responding yes, when asked to specify the methods or protocols that they used, responses included:

- "At the Sacramento Field Office of the U.S. Fish and Wildlife Service it was simply a ratio, typically 3:1, to offset the total habitat area impacted per species."
- Another respondent stated that they negotiated credits without using any established methods or protocols.
- Other methods cited were: cost-benefit analysis, wetland mitigation valuation method, or an acre-to-acre ratio (for Preble's meadow mouse habitat).

For the 87.5% of respondents that said no, they did not use methods or protocols to determine mitigation credits or values, they gave a variety of reasons for not doing so. The most often cited rationale was that there was an absence of a mechanism to assess or apply credits. Others mentioned that wildlife connectivity mitigation was a relatively new concept, and others stated there was no need to use credits to offset impacts. One respondent mentioned that there was no agency authorized to recognize such credits or values. Another indicated that it was difficult to give wildlife connectivity a quantitative value.

For the 5% of survey participants who said their state had in-lieu fee mitigation programs, they were asked how the credit requirements were calculated. Responses varied from credits are based on the mitigation that would have occurred on the transportation project's site, to credits based on the number of acres of habitat the project impacted, to a sliding scale of construction costs based on the project's impacts to a threatened species.

One response indicated costs for in-lieu program fees are 1:1. Another response stated that, if on-site mitigation is impractical or unachievable, a fee of 20% of the project is assessed that goes into the in-lieu program's coffers. Another explanation was that the costs per credit are spelled out in the Indiana bat range-wide in-lieu fee program.

Survey participants were asked if they used any methods or protocols to determine mitigation credits or values for transportation projects with impacts on wildlife connectivity. Over 87% of the responses stated that they did not use methods or protocols, and only 12.5% indicated that they did. Of those that replied yes, one person cited that they converted their mitigation credits into USACE wetland mitigation values. Another respondent stated they conducted a cost-benefit analysis, and another said for transportation projects that impact the endangered Preble's meadow jumping mouse, acre-to-acre ratios were used, based on whether habitat was temporarily or permanently impacted. Lastly, one respondent indicated that they negotiate credit values based on many different factors.

## 1.3 Potential Case Studies

The following transportation projects were mentioned by participants in the survey as either developing valuation or crediting metrics or could be instructive to such efforts:

- Caltrans, Laurel Curve Project
- Washington State DOT, I-90 Snoqualmie Pass East Project in Washington
- Florida DOT, State Route 40 Corridor; Valuing wildlife crossings: generating mitigation credit for the inclusion of wildlife crossings.

## 1.4 Key Findings

Survey results show that the development of crediting and valuation systems for wildlife crossings is in the early stages in less than a handful of states. However, there is keen interest in the development of mitigation crediting or banking systems for wildlife connectivity. Under current practice, only 12% of the respondents stated that they used mitigation on one project for use on another project (see Figure 17). However, more than half of the respondents to the survey indicated that, if their state provided the option to have a credit system for wildlife connectivity mitigation, they would take advantage of such a system (see Figure 20).

Survey respondents indicated that there are several states exploring the valuation or crediting of wildlife connectivity mitigation. Most are in the early development or exploration stages such as the Transportation Sub-team of the Panther Recovery Implementation Team in Florida. California's wildlife and transportation agencies are piloting a wildlife connectivity mitigation credit approach and have signed a credit agreement on the first pilot project, the Laurel Curve Wildlife Habitat Connectivity Project on Highway 17 in Santa Cruz County (Keeley et al. 2018) (See press release online at: https://cdfgnews.wordpress.com/2017/04/20/state-agencies-pilot-wildlife-crossing-mitigation-credit-system/).

# 2.0 FOLLOW-UP INTERVIEWS WITH KEY PRACTITIONERS

## 2.1 Characteristics of Key Practitioners Interviewed

For further insight into mitigation programs related to wildlife crossings and other enhancements, follow-up interviews were conducted with survey respondents that had extensive experience with wildlife connectivity mitigation programs within their state, which included Arizona, California, Colorado, and Florida. Interviewees included:

- 8 state DOT planners or environmental managers
- 4 wildlife biologists at state natural resource agencies
- 1 federal transportation agency

## 2.2 Practitioner Observations, Obstacles, and Recommendations

Wildlife connectivity mitigation projects pose unique challenges, such as a need for collaboration across agencies and jurisdictional boundaries, as well as the coordination of funding schedules and stakeholder objectives. Tailoring a mitigation crediting program to value wildlife crossings and other connectivity enhancements would address these challenges, but interviews with experienced practitioners revealed additional obstacles to overcome.

### 2.2.1 Legal, Planning, and Policy Framework for Wildlife Connectivity Mitigation

In general, the lack of regulatory requirements and processes requiring compensatory mitigation can be an impediment to the construction of needed wildlife crossings and other enhancements, except for instances where threatened and endangered species are affected or where wildlife connectivity is specified in the Purpose and Need of a NEPA analysis (Colorado Parks and Wildlife pers. comm. 2019). A survey respondent from the Idaho DOT (Idaho DOT pers. comm. 2019) said: “No coherent DOT policy or valuation of wildlife passage has been articulated by Idaho DOT leadership. Few of our long-range transportation plans incorporate wildlife passage as priorities for future action, barring compliance with federal land owners where we have road easements. Internal efforts have led to the production of a (now dated) prioritization plan for reducing WVCs as well as a recent MOU between Idaho DOT and Idaho Department of Fish and Game to coordinate on data sharing, collaboration, roadkill management but different districts have different views on what it means. So, there is spotty planning/implementation (lots of retrofits into other highway projects) toward a comprehensive treatment to provide wildlife passage across our transportation network.” Furthermore, because of the lack of regulatory requirements, public advocacy and conservation-focused NGOs have been a major motivating factor contributing to the construction of several wildlife crossing projects (Caltrans pers. comm. 2019, Arizona Game and Fish Department pers. comm. 2019). In some cases, citizen groups have formed specifically to advance the need for increased wildlife connectivity.

Extending mitigation crediting programs to include wildlife connectivity projects requires a move away from piecemeal, project-by-project mitigation approaches towards a collaborative approach for achieving species conservation. Although institutional challenges remain for creating a regional ecosystem framework that aligns state DOT goals and objectives with those of other resource agencies, numerous state DOTs have effectively coordinated with their respective state natural resource agencies to identify and prioritize landscape linkages or wildlife corridors. For example, a multi-agency MOU was developed by CDOT and other agencies (CDOT et al. 2008) for the I-70 Mountain Corridor programmatic environmental impact statement, which outlines shared vision for enhanced wildlife connectivity and reduced WVCs. An interagency committee (ALIVE) was formed and 13 areas were identified as potentially limiting wildlife migration (including elk, mule deer, bighorn sheep, and Canada lynx), referred to as linkage interference zones, and recommended mitigation actions that included enhancing existing or creating new wildlife crossing structures. Collaborative approaches such as this were widely supported by practitioners interviewed, although it was apparent that some state DOTs have better working relationships with USFWS and their state natural resource agencies.

Sciara et al. (2017) described how an Advance Mitigation Program could produce overall cost savings to state DOTs, largely due to reduced permitting delays and improved coordination and consultation with regulatory agencies. Current approaches to wildlife connectivity mitigation are not very effective or efficient because funding is often not available upfront, and wildlife crossing structures and other connectivity enhancements are often constructed only as funding becomes available. For example, the NEPA analysis for a 16.2-mile highway project in Colorado included 19 “multi-use” wildlife underpasses for deer and elk, but since signing the project Record of Decision in 2006, only one crossing has been constructed (Colorado Parks and Wildlife pers. comm. 2019). Using an Advance Mitigation Program would provide greater opportunity for state DOTs to implement wildlife connectivity mitigation projects. A practitioner with CDFW (pers. comm. 2019) highlighted three advantages of advance mitigation under its newly created RCIS program: (1) it would provide a cheaper and faster mitigation crediting process than traditional mitigation because approval is only required by one agency (CDFW); (2) it would allow for greater flexibility in terms of types of credits generated and methods use to quantify them; and (3) it would allow for temporary mitigation actions, such as non-permanent habitat enhancements, to quality as eligible for mitigation credits.

Wildlife crossings and other connectivity enhancements associated with transportation projects are usually justified by evidence documenting adverse effects of highways to populations of sensitive species. Because the regulatory framework for required mitigation differs depending on species status (e.g., federal or state threatened or endangered listing), the long-term application (i.e., demand) for mitigation credits could change in instances where the connectivity mitigation focus is on individual species. For example, the Platt Branch Wildlife and Environmental Area in Florida was acquired using funds paid by developers through the Florida Fish and Wildlife Conservation Commission's Mitigation Park Program (Florida Fish and Wildlife Conservation Commission 2017), but several of the species are no longer listed by the state (FDOT pers. comm. 2019). Changes to species status could affect future project prioritization and funding. However, the Florida black bear was removed from Florida’s Endangered and Threatened Species List in 2012, but FDOT has still proposed wildlife crossings for their benefit (Stantec 2019).

State DOTs may have concerns about encumbrances that may arise after construction of mitigation projects within the ROW, which could occur during highway expansion or other highway modifications. To address this concern with respect to wetland mitigation banking, the banking instrument typically includes language such as this: “If protected compensatory mitigation property is taken in whole or in part through eminent domain, the consequential loss in the value of the property protected by the USACE’s regulatory program is the cost of the replacement of the conservation functions, service and values of the aquatic and terrestrial resources on the compensatory mitigation property” (Wood and Martin 2016). Likewise, issues with wildlife crossings and other connectivity enhancements within the ROW could arise if there was a need to replace or repair structures due to reduced function. Although federal funds often largely pay for the construction of wildlife crossing structures, state DOTs bear the cost burden of maintenance (ARC Solutions 2017). Mitigation structures must be maintained and repaired to ensure their continued use and effectiveness (Cramer and Bissonette 2005). Imposing such requirements for the maintenance of wildlife connectivity mitigation projects was noted as a legal concern by a practitioner at FDOT (FDOT pers. comm. 2019). However, a California practitioner suggested that, because the mitigation would be within the ROW, it would be easier for Caltrans to uphold maintenance requirements when compared to other offsite mitigation projects (Caltrans pers. comm. 2019).

### 2.2.2 Valuation Metrics for Wildlife Connectivity Mitigation

Methods to quantify mitigation credits for a given wildlife connectivity mitigation project are not well developed. Only California has generated credits for a single wildlife crossing "pilot" project, and the credits were calculated based on structural, or condition-based, metrics. Although other function-based or model-based metrics could have been used, Caltrans used a simple condition-based metric to calculate the number of mitigation credits generated; the method used was inexpensive to calculate, and is straightforward and repeatable. Bennett et al. (2017) recommend that credits for mitigation markets incorporate measures of ecological function and biodiversity. State DOT practitioners in California and Colorado generally agreed that other metrics could have been used that would better relate to the ecological gain from the project but were not used because of several obstacles identified through this research (Caltrans pers. comm. 2019, CDFW pers. comm. 2019).

The input datasets and metrics used for various statewide or regional analyses of wildlife connectivity, as presented in the literature review, provide many potential metrics for calculating the ecological gain from a wildlife crossing or other enhancements. Analyses such as these are an essential first step for state DOTs to develop a program to value wildlife connectivity mitigation. However, to date, there are few metrics for which states may have adequate data to calculate function-based metrics related to wildlife enhancements. In particular, high-precision data exist from numerous studies of big game within the western United States, and most states maintain WVC data. However, a practitioner in Colorado suggested that, even with a large number of GPS collar data from numerous big game studies, the lack of comprehensive data from certain herds, including migration routes and seasonal habitat use, would be an obstacle to developing a metric that quantifies the ecological gain from a wildlife crossing structure (Colorado Parks and Wildlife pers. comm. 2019). This is in spite of the fact that big game are among the most easily monitored wildlife due to their large size and visibility.

The lack of data about other, more elusive focal species could be an even greater obstacle to developing mitigation credits for a wildlife connectivity mitigation project. For example, in Colorado, a CDOT practitioner suggested that, for low-density, wide-ranging focal species such as Canada lynx, it would be difficult to quantify mitigation credits for a wildlife connectivity project because the degree of benefit to Canada lynx (gain) would be difficult to measure. Although Canada lynx have been documented crossing at-grade over Colorado highways on numerous occasions, CDOT has not documented the species' use of existing wildlife connectivity mitigation projects in the state (CDOT pers. comm. 2019). Video surveillance (Dodd et al. 2007) or noninvasive genetic sampling (Clevenger and Sawaya 2009, Dixon et al. 2006), potentially combined with spatial capture-recapture models (Royle et al. 2017), could quantify increased habitat connectivity provided by wildlife crossing structures; however, these methods are not certain to be effective for Canada lynx. Furthermore, although the highway crossing behavior of Canada lynx has been studied in Colorado (Crooks et al. 2008, Baigas et al. 2016), the effects of various types of highway structures on Canada lynx are unknown and would be difficult to quantify in terms of mitigation credit debits. Lastly, another obstacle encountered could be that many data sets consist of observations and expert opinions gathered over decades and may not necessarily reflect current conditions because new development or other human impacts occur rapidly and could have altered the movements of focal species (Colorado Parks and Wildlife pers. comm. 2018).

Generally, planners and environmental managers at state DOTs support the use of ecological metrics (i.e., function-based metrics) for calculating the value of mitigation credits for wildlife crossings and other connectivity enhancements and associated debits for the impacts of transportation projects. Function-based metrics used to quantify credits would be based upon the estimated increase in wildlife connectivity that results from successful project implementation. To quantify increased wildlife connectivity, a potential metric would enumerate the number of individual wildlife, by species, identified to use the crossing structures. Several well-placed motion-sensitive camera traps can be placed at each crossing structure to measure its use by large-to-medium and even small body-sized mammals. These numbers can be compared to pre-construction numbers as measured by camera traps and/or track beds built along the edge of the highway at the mitigation site.

Another function-based metric could be the amount of roadkill reduced by the wildlife crossing. To calculate this metric, roadkill surveys would be necessary. Such surveys are often used to quantify wildlife mitigation needs (Costa et al. 2015) and state DOTs often have monitoring programs in place or have partnered with state natural resource agencies and/or universities to study roadkill. However, in some cases, due to very high traffic volumes, roadkill hotspots do not effectively indicate locations where wildlife connectivity mitigation is needed (Eberhardt and Fahrig 2013).

Mitigation credits could be quantified for wildlife connectivity mitigation by calculating an improvement in motorist safety via a measured reduction in WVCs. Reduction in WVCs is one common metric used in the literature to value wildlife crossings and was suggested by practitioners for quantifying improved motorist safety. A California practitioner highlighted the value of roadkill data collection for identifying areas where mitigation credit values should be highest for wildlife crossings and other connectivity enhancements that maintain or restore genetic connectivity for desert bighorn sheep (CDFW pers. comm. 2019). Because many state DOTs have existing programs for collecting data about WVCs, in certain situations, this metric could be among the most straightforward metrics available to calculate mitigation credits for wildlife connectivity projects. In California, Shilling et al. (2018) evaluated WVCs and identified stretches of highway where WVC are most likely. They reported five recommendations that would apply to state DOTs seeking to apply mitigation credits for wildlife crossings that use a motorist safety metric as part of the credit calculation: (1) systematically collect and share WVC data; (2) require collection and analysis of WVC data for transportation projects before they are approved and funded; (3) protect driver safety and wildlife by building WVC-reduction projects; (4) form new partnerships among university and NGO scientists, citizen groups, and local agencies interested in reducing WVC impacts; and (5) systematically evaluate effectiveness of WVC reduction to keep improving.

Whatever methodology is used to calculate mitigation credits for wildlife connectivity mitigation, the practitioners interviewed generally agreed that there should be consistent quantification of both debits (impacts) and credits (benefits). Ideally, the metrics used to calculate wildlife connectivity mitigation credits should be based on the focal species' biology, would be easy to measure, and include communication among stakeholders. Because different species have widely variable life histories, habitat requirements, and dispersal abilities, there are inherent difficulties to accommodating the needs of multiple species (Mimet et al. 2016); quantifying mitigation credits for multiple focal species would prove equally challenging. When asked about the metrics potentially used to value mitigation credits, in general, most practitioners interviewed responded that "it would depend on the species." Also, when asked if the calculation of mitigation credits for wildlife connectivity projects should be based on metrics for single or multiple species, practitioners responded that only single species metrics seem feasible.

Highly mobile species requiring large habitat area are the most sensitive to highways (Mimet et al. 2016), which would also include the large mammals that are economically valuable for recreation and/or more costly in terms of vehicle damage and human injuries due to WVCs. Thus, metrics used to quantify the value of wildlife connectivity mitigation would be most likely based upon populations of large-ranging mammals. Furthermore, the context of the surrounding ecosystems differs greatly among wildlife crossing structures, so mitigation credit agreements and metrics could differ widely among projects. State guidelines for the development of mitigation credit agreements could suggest types of metrics recommended based on previous analysis and available types of datasets. However, every mitigation credit agreement would differ, and it would likely be necessary to negotiate mitigation credit agreements for wildlife crossings and other connectivity enhancements on a case-by-case basis, which is the current approach taken by CDFW (pers. comm. 2019).

Developing a standardized currency for wildlife connectivity mitigation credits is difficult because the metrics used to quantify wildlife connectivity differ among species. For this reason, wildlife crossing structures and other connectivity enhancements are generally designed to enhance connectivity for a small number of focal species known to be adversely impacted by the lack of permeability at that site. For some focal species, it would be reasonable to define a single metric, or set of metrics, that could be used to quantify the value of wildlife connectivity mitigation for that particular species, in that particular landscape in terms of population abundance, animal movement (e.g., GPS-collared animals), roadside habitat quantity and quality, or/and genetic diversity. Also, for some focal species, researchers have developed models that could inform credit valuation for wildlife crossing connectivity mitigation, which could include distribution models, animal movement models, and habitat-based population viability models. Confidence in the application of models to the valuation of wildlife connectivity mitigation will be greatest if they have been validated to assess their predictive power on other road sections in similar landscapes (Gunson et al. 2011).

The valuation of wildlife connectivity mitigation explored by this research is improved when empirical biological data exists for each target species on a road-by-road basis in order to identify the most cost-effective decisions. Decision makers need information on the ecological importance of each linkage area and ways to identify the most important linkages. Typically, a suite of focal species and associated habitats are identified that have the greatest need for enhanced connectivity. When cost is not a consideration, developing a crediting system for wildlife connectivity mitigation actions would require a robust analysis of focal species' habitat and movement patterns, including migration corridors, breeding sites, and seasonal ranges, and how they are impacted by transportation infrastructure. CDFW (pers. comm. 2019) suggested that they anticipate that future mitigation credit agreements for wildlife crossings or other connectivity enhancements will consider these factors to quantify ecological gain, such as improved access to breeding sites or improved gene flow.

Statewide prioritization of wildlife crossings, or regional prioritization in large states such as California, would be a necessary first step to developing a mitigation credit program for big game wildlife crossings or other enhancements. However, some statewide analyses have identified large numbers of unprioritized corridors, such as 232 corridors in California (Penrod et al. 2001) and 150 corridors in Arizona (Nordhaugen 2006). Although such analyses may be biologically accurate in terms of threats to connectivity, transportation planners need more detailed information on the ecological importance of each linkage area, and some way to identify the most important linkages. To address this issue, several collaborative projects have prioritized wildlife connectivity mitigation by considering collision risk to big game and motorist safety, such as those in Idaho (Cramer et al. 2014) and Colorado (Kintsch et al. 2019). In California, the RCIS program developed by CDFW would provide finer scale details about the species and habitats associated with each linkage in the context of regional conservation priorities.

Because there is no existing mitigation program of its kind in the United States, CDFW's RCIS program has a flexible framework that allows for project proponents to propose the metrics used to calculate mitigation credits (CDFW pers. comm. 2018).

Once stakeholders agree about the metrics used to calculate mitigation credits for a wildlife connectivity mitigation project, there could be uncertainty about the accuracy of protocols to quantify credits. However, wildlife connectivity mitigation is a collaborative effort between individuals with expertise in both ecology and transportation infrastructure, so the best available science and local knowledge would be used to develop mitigation credit agreements. Furthermore, each mitigation credit agreement in

California would be subject to public comment, which would provide another level of scrutiny of the protocols used (CDFW pers. comm. 2018).

Before creating a system for wildlife connectivity mitigation banking, demand for such mitigation must be assessed. In the *Results from a Survey of Conservation Banking Sponsors and Managers*, DOI (2018b) found that one of the most substantial obstacles for conservation banking is that demand for bank credits is often weak or poorly understood. Therefore, as part of its Advance Mitigation Program, Caltrans is performing a statewide advance mitigation needs assessment that will quantify the demand and estimate the potential impacts of future planned transportation projects. Impacts are estimated by overlaying transportation project footprints with natural resource data layers and will be used to determine regions for regions for conceptualizing advance mitigation projects. Once the statewide needs assessment is completed, Caltrans will develop regional advance mitigation assessments within the identified regions, identify conservation goals and objectives, identify conservation plans and recovery plans for focal species, and identify existing mitigation opportunities (Caltrans pers. comm. 2019).

Credit issuance under conservation banks approved by USFWS must use the same system (i.e., metrics) to quantify both the biological values of mitigation sites and the adverse impacts of the development for which the credits will be used as mitigation (DOI 2013). In some instances, mitigation ratios are used to ensure that mitigation is proportionate to the impact being offset. For example, if a transportation project will affect the movement of an estimated number of migratory mule deer, then the wildlife crossing or other connectivity enhancement used for mitigation should provide benefits to a greater number of mule deer. USFWS (2003) notes that the use of mitigation ratios must be based on sound biological rationale that is easily explained, readily understood, and consistently applied. Establishing equivalency between project impacts and mitigation credits is generally straightforward for conservation banks, where metrics are easily quantifiable such as acres of habitat or the number of breeding pairs of a species. However, for wildlife connectivity mitigation, this approach is less straightforward. Practitioners interviewed from California, Colorado, and Florida did not have experience using any metrics that could be evaluated for equivalency between the ecological gain from a wildlife crossing or other connectivity enhancement and the ecological loss from a transportation project.

### 2.2.3 Monitoring and Performance Requirements

As with other forms of compensatory mitigation, it is essential to monitor the effectiveness of wildlife connectivity mitigation projects to ensure they meet their objectives of reduced impacts on wildlife, increased highway crossings via mitigation structures, or improved motorist safety. Monitoring would verify if the ecological gain from a wildlife crossing or other enhancement adequately offsets impacts from other transportation projects. In wetland mitigation banks and conservation banks for threatened and endangered species, such performance standards or release criteria are typically required to be met before credits can be sold. However, for wildlife connectivity mitigation, the lack of standard procedures and criteria for monitoring performance standards could be an obstacle to implementing a mitigation crediting program. Standard monitoring protocols would need to be developed that are cost-effective to implement and able to conclusively measure performance standards for focal species. Although most wildlife crossing structures in the United States are monitored to evaluate their effectiveness at providing wildlife passage, according to practitioners surveyed, few projects have had clearly defined success criteria other than documenting their use by wildlife.

One of the most straightforward metrics used to evaluate the effectiveness of a wildlife connectivity mitigation project would be to measure increased driver safety via the number of reduced WVCs after implementation. To quantify WVCs, most state DOTs have data-collection protocols in place. In Colorado, CDOT has standard operating procedures for collecting data about all accidents involving wildlife from the Colorado State Patrol (CDOT pers. comm. 2019). In Arizona, WVC data are collected via a smartphone application, Survey123 for ArcGIS, which is shared among state agency staff (AGFD pers. comm. 2019). A similar smartphone application is used by the South Dakota DOT to collect and store WVC data (Cramer 2017). Also, perhaps more than any other impact of highways on wildlife, roadkill is clearly quantifiable and has been very well documented, so roadkill surveys could be used to monitor the effectiveness of a wildlife connectivity mitigation project. Colorado has standard operating protocols for collecting carcass information anytime CDOT staff handles roadkill or wildlife injured by a vehicle (CDOT pers. comm. 2019). Utah collects similar data and publishes it online (https://mapserv.utah.gov/wvc/desktop/). However, there are no standardized road survey protocols and only a handful of studies have sought to identify the optimal sampling approach needed for roadkill surveys of different taxa (Bager and Rosa 2011, Ford et al. 2011, Costa et al. 2015). Furthermore, several biological considerations must be considered if roadkill is used as a metric for evaluating the effectiveness of wildlife connectivity mitigation, such as the relationship between roadkill and surrounding wildlife population abundance, and the road avoidance behavior of some species in response to traffic volume (i.e., roadkill rates decrease as traffic volume increases because animals are less likely to cross the road) (Teixeira et al. 2017).

For most function-based metrics that could be used to quantify credits for a wildlife connectivity mitigation project, it would be necessary to monitor animal through-passage of a wildlife crossing structure or other enhancement. If the release of mitigation credits depended upon such a performance standard, a Colorado practitioner suggested that a standard monitoring approach would be necessary to evaluate whether it is effective at providing the promised levels of through-passage to focal species (CDOT pers. comm. 2019). Although most wildlife crossings built in the U.S. have been monitored via remote cameras to verify their usage by focal species (e.g., Cramer and Hamlin 2016), standard protocols are not typically used (Caltrans pers. comm. 2019; FDOT pers. comm. 2019). In a review of the state of the practice over a decade ago, Cramer and Bissonette (2005) found that a limited number of the 460 terrestrial wildlife crossing structures in the U.S. were monitored for effectiveness. Texas DOT has created several ocelot crossings in recent years, but few have been monitored long-term, so no standard guidelines for ocelot crossings have been developed or validated (USFWS 2015b). Currently, only a few states have developed standardized methods for wildlife crossing structure monitoring, including Montana, Idaho, Oregon, Washington, and Utah (Kintsch and Cramer 2016). The scope of most monitoring elsewhere is typically narrow, focusing primarily on larger carnivores and ungulate, and almost exclusively on use of the structures. In Colorado, few practitioners have followed standardized protocols and only some have documented the presence of focal species (Kintsch and Cramer 2016, CDOT pers. comm. 2019.). For other enhancements, such as fence construction or removal, retrofits to existing structures (e.g., culverts), or jump outs, the lack of standard monitoring protocols would make the establishment of a performance standard and credit release schedule even more difficult.

Another consideration for the metrics is the duration of required monitoring. CDFW (pers. comm. 2019) suggested that, under the RCIS program, future mitigation credit agreements for wildlife connectivity mitigation would likely include short-term monitoring to evaluate performance standards (i.e., credit release), and long-term monitoring and maintenance to ensure continued effectiveness. The monitoring specified in a mitigation credit agreement would be determined by the metric used to quantify credits and the biology of the focal species and should consider any available past research. For example, monitoring studies of wildlife crossing structures and other connectivity enhancements have shown that, in general, wildlife use increases slowly over time, over as many as 10 years and varies by species. Thus, for some species, short-term monitoring for less than this duration may mislead stakeholders about the ultimate effectiveness (i.e., ecological gain) of a wildlife connectivity mitigation project (Huijser et al. 2008).

In summary, although state DOTs have existing WVC and roadkill data-collection programs that could be used to calculate mitigation credits and monitor wildlife connectivity mitigation, the use of such data would depend on the focal species and may not be applicable to many taxa. These metrics could reasonably be used under certain situations to value wildlife crossings and other connectivity enhancements for big game, especially when used in combination with GPS collar data. Also, for many focal species, developing cost-effective performance standards for credit release would present an obstacle that would need to be overcome before mitigation credits could be generated, which would likely be determined on a project-by-project basis via mitigation credit agreements.

#### 2.2.4 Funding Mechanisms and Program Costs

Lack of available funding is the greatest obstacle to deploying wildlife crossings and other connectivity enhancements associated with transportation projects (Kociolek 2014, Ament et al. 2015). As noted through the interviews, wildlife connectivity mitigation is typically funded on a case-by-case, project-by-project basis as part of a larger transportation improvement project. Furthermore, transportation project timelines vary greatly, potentially causing a planned wildlife connectivity mitigation project to be misaligned with funding sources, such that mitigation opportunities could be missed. The IEF provides a useful approach for funding wildlife connectivity projects via mitigation credits under an Advance Mitigation Program, which would serve to address many predictable adverse impacts to wildlife resulting from future transportation projects. After project-specific avoidance and minimization measures are taken, unavoidable impacts could be offset by purchasing credits from out-of-kind wildlife crossings and other connectivity enhancements.

Effective wildlife connectivity mitigation along highways is expensive: recently constructed wildlife structures in Colorado cost about $300,000 to $2,950,000, with associated fencing ranging from $200,000 to $1,050,000 (Kintsch et al. 2019). Because of this high expense, state DOTs do not generally have dedicated funding for wildlife connectivity mitigation projects. Projects are usually constructed based upon opportunity, either to mitigate a proposed transportation project or where strong public interest exists for conserving economically valuable species (e.g., big game). Practitioners consistently pointed to the lack of funding as one of greatest obstacles to constructing wildlife crossings and other connectivity enhancements. To complete wildlife crossing projects, multi-stakeholder partnerships are thus often necessary to leverage funding. Nevada DOT’s (2018) *Prioritization of Wildlife-Vehicle Conflict in Nevada*, in chapter 7, provides an excellent overview of funding resources for wildlife connectivity mitigation, including the available federal programs and other potential funding from local governments, non-profit organizations, and citizen initiatives.

Lack of funding for wildlife crossings and other connectivity enhancements is largely because the funding of transportation projects gives priority to motorist safety over impacts to wildlife. The cost of WVCs, in terms of motorist death and injury, are usually less than the costs from other factors contributing to hazardous highway conditions. Therefore, although highway segments with elevated WVCs are high-priority mitigation areas in terms of motorist safety, other highways with more frequent motorist injury or fatality are often a higher priority to state DOTs. Under most existing state DOT funding programs, wildlife connectivity mitigation projects must compete with other highway safety projects and often do not receive funding because they would provide less benefit in terms of motorist safety. Their benefits to focal species are currently not considered (CDOT pers. comm. 2019).

The in-lieu fee program to fund highway mitigation for Canada lynx in Colorado (FHWA et al. 2015) has not been used for any CDOT projects, so the account balance is $0. When asked why, a CDOT practitioner stated that transportation project managers in the state have found methods to implement on-site avoidance and minimization for projects so that fee payments have not been necessary. From one standpoint, the program has thus been successful because it has motivated transportation project managers to find ways to avoid an adverse determination of effects to Canada lynx (CDOT pers. comm. 2019). However, the lack of funding was not the program's intent. A downside of the in-lieu fee program highlighted by CDOT practitioners was that project managers do not prefer to contribute limited project funding to an offsite mitigation account but would rather see those funds spent on their own project(s). If money was taken from state transportation funding before it was allocated to regions or to specific projects, transportation engineers and project managers would not view the Canada lynx in-lieu fee program as a potential financial burden and would be more willing to use it (CDOT pers. comm. 2019).

Other practitioners also suggested that one of the major advantages of developing a wildlife connectivity mitigation crediting program would be the creation of a dedicated funding source for wildlife crossings and other connectivity enhancements. However, establishing a sustainable statewide funding source for wildlife connectivity mitigation could be a significant hurdle to overcome in many states. In California, Thorne et al. (2015b) suggested that, for advance mitigation funding, mandating that a percentage of all transportation project funding be committed to compensatory mitigation would provide Caltrans with funding to purchase mitigation credits before transportation projects have been programmed. Thorne et al. (2015b) further caution that advance mitigation funding should not be reliant on funding sources that could expire. An alternative recommendation to advance mitigation could be to develop a state-sponsored in-lieu fee program for funding wildlife mitigation, which could include wildlife connectivity.