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Making habitat connectivity a reality

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Abstract

For over 40 years, habitat corridors have been a solution for sustaining wildlife in fragmented landscapes, and now are often suggested as a climate adaptation strategy. However, while a plethora of connectivity plans exist, protecting and restoring habitat connectivity through on-the-ground action has been slow. We identified implementation challenges and opportunities through a literature review of project implementation, a science-practice workshop, and interviews with conservation professionals. Our research indicates that connectivity challenges and solutions tend to be context-specific, dependent on land ownership patterns, socioeconomic factors, and the policy framework. We found evidence that developing and promoting a common vision shared by a diverse set of stakeholders including nontraditional conservation actors, such as water districts and recreation departments, and through communication among and between partners and the public is key

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to successful implementation. Other factors that lead to successful implementation include undertaking empirical studies to prioritize and validate corridors and the identification of related co-benefits of corridor projects. Engaging partners involved in land management and planning, such as non-governmental conservation organizations, public agencies, and private landowners is critical to effective strategy implementation. A clear regulatory framework including unambiguous connectivity conservation mandates would increase public resource allocation, and incentive programs are needed to promote private sector engagement. We argue that connectivity conservation must more rapidly move from planning to implementation and provide an evidence-based solution made up of key elements for successful on-the-ground connectivity implementation. The components of this new framework constitute the social processes necessary to advance habitat connectivity for biodiversity conservation and resilient landscapes under climate change. Three case studies serve to illustrate the application of the framework.

Introduction

Conversion of natural areas for human use continues to lead to habitat loss and fragmentation, species declines and ecosystem degradation (Haddad et al. 2015). For over four decades, wildlife corridors that mitigate the impact of habitat fragmentation have been an important tool for maintaining landscape connectivity, resulting in a variety of corridors, linkages, and wildlife-friendly road crossings all around the world (Hilty et al. 2012). There are also many ambitious efforts to connect protected areas at the continental scale including the Yellowstone to Yukon Conservation Initiative in North America, the Gondwana Link in Australia, and the Mesoamerican Biological Corridor (Shadie & Moore 2008). However, with habitat loss and fragmentation continuing rapidly (Theobald et al. 2016), and climate change

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driving species range shifts (Hannah 2011), there is an urgent need to speed up the rate of habitat connectivity project implementation.

Many local, regional, or national connectivity studies and plans exist (e.g. Merenlender et al. 2010), but implementation has been slow (Tiemann & Siebert 2008). The failure to translate connectivity research and scientifically-informed plans into conservation action is a phenomenon often referred to as "the research-implementation gap" or "planning-implementation gap." This gap can potentially be bridged by scientists engaging with conservation practitioners throughout an entire project, from the initial study questions through project implementation and monitoring (Knight et al. 2008). Because academic norms do not often promote such long-lasting engagement, Cook et al. (2013) suggested that applied conservation science should be conducted by scientists working within resource management agencies or environmental organizations, or involve formal agreements between practitioners and academic scientists to ensure comprehensive collaboration. However, Toomey et al. (2017) note that "conservation is a social process that engages science, not a scientific process that engages society" and argue that we need to re-conceptualize the planning-implementation gap as a space that needs to be filled by a diversity of social processes to achieve conservation implementation.

Here we investigate the challenges and opportunities that typically confront the process of moving from connectivity conservation planning to implementation by examining the available literature, as well as the personal experiences from practitioners working on a diverse array of projects. From these findings, we distilled critical components to successfully implement connectivity projects on the ground, considered the relationships among these components, and created a framework to guide future efforts. The components of the framework constitute the social processes necessary to enable successful implementation of scientifically informed connectivity planning. While there will never be a magic bullet to

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ensure successful implementation, this thorough analysis of the challenges and successes encountered in a variety of implementation projects can help future implementation efforts be successful.

Scholarship

Although corridor science is a well-studied field, published literature on corridor implementation is limited. We define “corridor” as spatially constrained habitats that provide connectivity between larger habitat areas. We found 27 peer-reviewed papers, 13 reports and five book chapters that included information on implementation and corridors in Web of Science and the top 100 Google search results in May 2017 (Supporting Information).

To improve our understanding of factors that may increase or jeopardize success of connectivity implementation projects, we conducted 30 interviews with practitioners in conservation organizations and public agencies. The interview protocol was approved by the Committee for Protection of Human Subjects of the University of California, Berkeley (Permit Number: 2016-09-9118). We also convened scientists and practitioners from resource agencies and organizations to brainstorm ways to best plan and implement connectivity in the face of continued human land use and climate change. The interviews and workshop were conducted with practitioners in California where connectivity projects span a diversity of socio-ecological contexts and institutional participation. Interview questions were formulated to obtain information on the interviewee’s role with respect to connectivity conservation, background on the project, the type of information used for planning, and perceived challenges and opportunities encountered during implementation (Supporting Information).

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Challenges and opportunities

Our review of the literature found that the challenges and opportunities to corridor implementation are varied, context-specific, and depend on land ownership patterns, the intensity of development and fragmentation, socioeconomic factors, institutional capacity, and the regulatory framework (Supporting Information; Worboys & Lockwood 2010; Fitzsimons et al. 2013; Brodie et al. 2016). What is a challenge in one context may be an opportunity in another. For example, political support, when present is an opportunity, but when absent a challenge. Challenges can be based on customs, values, or belief that projects will have negative impacts on the rights and economic opportunities of landowners (e.g. Naumann et al. 2011, Supporting Information). They can stem from historical factors such as ingrained land use patterns, or a lack of alignment among project partners. Lack of funding, and political will causes challenges as will lacking project or political leadership. We discuss strategies to overcome these challenges and take advantage of opportunities in six broad categories that consolidate the diversity of perspectives in the field.

Build partnerships

Building partnerships is a key strategy for corridor implementation in regions with diverse landownership. Public-private partnerships are a powerful opportunity for accomplishing on-the-ground implementation, because the two can complement each other (Naumann et al. 2011; Gleason et al. 2013). In some situations, private landowners refuse to deal with public agencies due to previous negative experiences with laws and regulations, but the door may be open to non-governmental organizations (NGOs). Private landowners and NGOs can often respond quickly to specific project needs. They can also attract and manage private charitable foundation funds, which are more flexible than agency funds (Gleason et

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al. 2013). Public agencies manage public lands and public funds, the transportation network, and natural resources, and therefore are essential partners in connectivity conservation.

Involving agencies at the right levels and engaging people in the right position of the agency hierarchy can be challenging. While for some high-profile agency-led projects involvement of agency leaders may be advantageous, for many projects such as road wildlife mitigation projects agency staff can address connectivity aspects in their routine work. For the latter to occur, agencies need to be required to address the issue of landscape fragmentation and have policies mainstreaming connectivity considerations in everyday decision-making (Morrison & Boyce 2008).

While many projects are started by one individual with drive, energy, passion, and commitment who inspires others to participate (Fitzsimons et al. 2013; Pulsford et al. 2015), a collaborative team is key to maintaining momentum and ensuring succession of leadership (e.g. Tiemann & Siebert 2008). Involving diverse stakeholders as equal partners from the beginning, and maintaining regular communication is key to success. Early participation improves understanding of the need for and approach to connectivity conservation, increases buy-in, and encourages continued involvement (Rottle 2006; Jongman 2008). Ongoing dialogue and information exchange gives partners and communities a sense of ownership and responsibility (e.g. von Haaren & Reich 2006). In general, an atmosphere of cooperation promotes productivity and success, but as relationships get complicated, professional moderators may need to be engaged on a regular basis (Tiemann & Siebert 2008). While seen to be more effective in the long-term, collaborative efforts with multiple partners also take longer to develop. When there are many partners, organizing leadership into a core team may be necessary.

Diverse private landownership can pose a challenge to connectivity implementation (e.g. Naumann et al. 2011). Opportunities to assign private lands conservation status can

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advance implementation of corridors. Involving landowners as critical partners, who have defined rights and responsibilities in the connectivity project, and, if necessary, entering into formal agreements to manage land across property boundaries are avenues that can lead to success.

Develop a common vision

Establishing a common vision of a connected landscape that integrates social, ecological, and economic outcomes proposed by partners and stakeholders is essential and can generate energy and enthusiasm among stakeholders, and create a momentum for project implementation. The process of developing a shared vision during multi-partner regional planning processes allows people with different interests and priorities to express their concerns and aspirations for the project that either can be addressed or at least acknowledged so that, for example, if land needs to be removed from production this will not come as a surprise to the community and compensation can be discussed (Beunen & Hagens 2009; Goldman 2009; Wyborn 2015). Once a shared vision is established, priority areas for restoration or conservation can be determined by the participating stakeholders (Beunen & Hagens 2009). The resulting increased public engagement for a local project can also influence government to adopt regulations focused on advancing connectivity conservation

In Australia, the conservation community recognized that it could slow species loss and the effects of climate change by facilitating species movements. This shared vision of connected landscapes to conserve biodiversity in the face of climate change resulted in a social movement (Pulsford et al. 2012) and has led to the drafting of a National Wildlife Corridors Plan and connectivity initiatives in every state of Australia (Wyborn 2015).

In several European countries, despite a strong vision for a connected landscape resulting in planning efforts at multiple scales and policies at the European and national

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levels, little progress beyond planning has been made (Beunen & Hagens 2009), indicating that a vision alone may not be sufficient for successful implementation. Lack of public engagement, no deadline for network completion, deficiencies in legal definitions, and a history of conflict between resource agencies and landowners were offered as explanations for implementation failures (Tiemann & Siebert 2008).

Communicate with partners, stakeholders, and the public

Regular meetings of project partners, conferences, and webinars facilitate coordination and upholds interest (Rottle 2006; Tiemann & Siebert 2008). This is vital when unconventional partners with different interests are involved, such as counties, business communities, and developers. To retain stakeholder interest and promote a feeling of progress, defining a set of measurable criteria for success, developing a transparent strategy for monitoring progress, and agreeing on a regular review process for approved projects can help (Dettman 2006; Tiemann & Siebert 2008). Clearly communicating the goals and objectives of a connectivity project, openly discussing a project's implications for the landowners, and acknowledging and addressing the financial realities of conservation on private land are important aspects of building trust. For larger, complex projects, early success can lead to greater acceptance in the community. Thus, starting out with easy steps, such as visible small stewardship projects, is recommended (e.g. Rottle 2006). Specifying realistic timelines for completing the various phases of a connectivity project is necessary to avoid delays and potential failure (Tiemann & Siebert 2008).

Outreach campaigns are an important strategy for building public support, which can be critical for implementation success (Dettman 2006; Naumann et al. 2011). Depending on the goal, the audience can be the public, specific communities, private landowners in priority areas, or for the longest time horizon, children. The objectives can be short-term - sharing

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information about a specific project, or long-term - educating the public about the effects of habitat fragmentation and the resulting need for landscape connectivity. Outreach campaigns serve to broaden the base of support for implementation among private landowners and enhance trust between NGOs and/or agencies and local communities. The adoption of charismatic flagship species can play an important role in communicating the concept and need for connectivity conservation among local communities (Tiemann & Siebert 2008). Wildlife studies can be a good tool to engage with the public, because the resulting photos, videos, and movement paths of charismatic animals provide an opportunity to inspire people. For high-profile projects, a formal public outreach strategy with in-depth and widespread media coverage on implementation progress can enable successful implementation (Schlotterbeck 2012).

Forms of communication can include websites and social media, newspaper columns, newsletters, public presentations, workshops, school visits, field trips, volunteer days, and one-on-one communications with landowners (Fitzsimons et al. 2013). When communicating with the public, the use of stories and non-technical, evocative language are most effective.

Base implementation on sound science

All projects rely on a combination of empirical data such as animal movement (e.g. from telemetry studies, camera traps, roadkill surveys, and/or genetic studies), connectivity and prioritization models, and expert input aid in planning, prioritizing, and validating connectivity zones and corridors. Coarse-scale analyses are important to inspire and guide connectivity action, but individual projects need to be informed by detailed, fine-scale plans (Beier et al. 2011). Having animal movement data for a specific linkage can help convince stakeholders of the need for implementation (White & Penrod 2012), and can garner political support and funding (Naumann et al. 2011). While scientists should design field research and

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conduct analyses, involving partners in the discussion about study objectives, input parameters, and focal species will make the process transparent and inclusive, and consider partners' perspectives and local knowledge (Beier et al. 2008). A high level of stakeholder participation from the project's inception will increase the likelihood that the stakeholders will follow through with the final research-driven recommendations. In addition to the need for scientific data, interviewees noted that the level of project staff expertise can limit their ability to implement and manage for habitat connectivity. Staff training on landscape fragmentation effects, interpretation and use of connectivity data, and guidance on how to work with modeled outcomes could be useful.

Seek to create multiple benefits

Multiple benefits can emerge from land protection and restoration, including increased potential for species to adapt to climate change, carbon sequestration, improved water quality, recreation, and preservation of open space and working lands. Promoting these benefits in addition to protecting wildlife and biodiversity can be an opportunity to increase support for connectivity projects in areas with diverse landownership (e.g. Jongman et al. 2008; Beunen & Hagens 2009). Coalition building by involving multiple partners whose objectives align with these co-benefits, including nontraditional conservation actors such as water districts, planning agencies, and recreation departments, is an opportunity for increasing advocacy, tapping a greater variety of funding sources, and improving the odds of overcoming barriers toward implementation.

In some regions, finding means of integrating conservation and economic development, e.g. by developing sustainable forestry or extensive land farming practices in corridors, can be beneficial for successful connectivity implementation (Bennett 2004). However, in some cases, the corridor implementation effort was combined with the goal of advancing local

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economic development, which detracted from the original purpose of biodiversity conservation. Because information about biodiversity conservation was lacking at the local level, economic development originally tied to implementing the biological corridor became the main focus and the corridor concept was re-interpreted in an economic sense, now referring to, for example, ecotourism corridors (Dettman 2006). Hence, associating a corridor project with multiple benefits can be a double-edged sword when it comes to operationalization (Naumann et al. 2011). Effective communication of the primary ecological objectives and creation of baseline ecological data and a monitoring program are critical to ensure project goals are met. Specifying how other benefits are synergistic with primary objectives, and providing guidelines on how to manage or restore land in corridors will help reconcile conflicting objectives as more stakeholders and goals are bundled into single projects (Dettman 2006).

Adopt regulations, incentives, and funding mechanisms

Resource agencies interested in advancing habitat connectivity on the ground argued for binding regulations as compared to guiding regulations as important for success even though in some countries land policy regulations have become so complex that potential players avoid becoming involved (Beunen & Hagens 2009). A legal framework requiring government agencies to include connectivity conservation considerations in project planning can ensure early internal and external coordination of connectivity projects between agencies with different mandates (Shadie & Moore 2008). Without such a framework, action is left to motivated employees who act without the support of the agency’s bureaucracy, resulting in piecemeal connectivity implementation.

Some interviewees cautioned against promoting connectivity through laws that regulate private landowners because perceived over-regulation can result in a decreased willingness to

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participate in conservation projects. Instead, they reported successful projects led by private conservation organizations and implemented independent of regulations and emphasized the need for strong, voluntary incentive programs with cost-sharing for compatible land uses, and consensus-based approaches (see also e.g. Rottle 2006; Morrison & Boyce 2008).

While regulations can instigate conservation action and justify the need for connectivity implementation to the public, without funding it can be difficult to comply with regulations. Not surprising, many practitioners noted that funding for on-the-ground efforts is a pre-requisite for successful implementation. Incentive programs can be coupled to regulations at the national, state, or local level, or be site-specific and can be run by governmental agencies, private organizations, or public-private partnerships. An array of alternative funding strategies was listed by interviewees including: fundraising from individuals, applying for public funds, creating public-private partnerships, planning multi-benefit projects, linking to climate adaptation funding, using seed money to grow successful projects, developing partnerships with businesses, and taking advantage of volunteers (see also Bennett 2004).

A specific challenge arises when a pinch point corridor needs to be protected where key lands may be relatively small but very expensive and slated for city development. While environmental regulations can be an opportunity to advance corridor implementation, often, these small parcels do not harbor listed species, rare habitat types, or other statewide priority resources for conservation, and thus can be harder to fund with sources that focus on threatened and endangered species. Agency resource professionals noted that even with local land use and state guiding regulations that may pay homage to the benefits of habitat connectivity, real regulatory requirements and funding mechanisms are often absent, making it difficult to retroactively incorporate connectivity measures into existing highways. They argue that a funding source specifically for habitat connectivity projects would make project implementation in this and many other instances more feasible. Funding increasingly

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available through climate change adaptation programs is a new source of connectivity funding when used to strengthen the practice of "climate-wise" connectivity conservation. Even with funding, regulations provide important motivation and justification for resource agencies to engage in habitat connectivity efforts.

An evidence-based framework and illustrative case studies

In light of these findings, we propose a framework to guide on-the-ground connectivity implementation (Fig. 1). This framework shows how the evidence-based elements we synthesized from interviews and the literature are critical to the implementation process including: the role of partnerships, planning, data and analysis, opportunities and challenges, and various strategies to produce conservation outcomes. Our framework builds on existing frameworks to guide conservation action with a focus on connectivity conservation and emphasizes the role opportunities and challenges can play in establishing corridors and other on-the-ground solutions (e.g., Margules & Pressey 2000, Salafsky et al. 2001, Bunnefeld et al. 2017, http://cmp-openstandards.org/). We illustrate the components included in the framework with three case studies to demonstrate that it can be applied across multiple contexts (Fig. 2., Table 1). The projects range from local to landscape scales and differ in their ecological objectives (Fig. 1A): reducing wildlife road kill and facilitating animal movement, connecting large landscape blocks and facilitating range shifts, and endangered species recovery and ecosystem resilience. The projects rely on different data sources (Fig. 1B). While the first project mostly used wildlife presence and movement data the other two projects integrated a broad array of land cover and land use change information as well as climate information. Partners varied from federal land management and state agencies to private land trusts. The final conservation outcomes (Fig. 1-E) are a corridor, a landscape linkage, and conservation of a permeable landscape.

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Highway 17 Crossing

This highway project was triggered by frequent vehicle-wildlife collisions on a busy highway. Although California's regulatory context encourages agencies to consider wildlife connectivity in new project designs (CA-AB498), retrofitting existing highways was not part of standard procedures and was lacking funding sources. However, concern for human safety presented an opportunity (Fig 1-C) for the Department of Transportation to engage with conservation organizations concerned about the barrier effect of the highway and work on a wildlife crossing project. The local land trust raised funds to protect land on either side of the proposed highway crossing. University researchers collected extensive biological data and modeled regional wildlife connectivity to determine the best location (Fig 1-B), and inform a media campaign to generate public and agency support (Fig 1-C). The main challenge that remained after garnering public and agency support, deciding on the best site and design for a wildlife tunnel, and securing the surrounding properties, was funding for the structure itself. Realizing that the need for mitigating existing highways was not limited to this location, the partners developed a pilot agreement for using advanced mitigation credits to fund connectivity projects that, if successful, can be applied throughout California. Thus, strategies that were employed to make this project happen were the collection of extensive biological data, a media campaign that ensured public support, partners that secured land on both sides of the highway, and the development of a creative strategy to fund the crossing structure itself. Implementation of the crossing structure (Fig 1-D) is slated for completion in 2020.

Sonoma Valley Wildlife Corridor

The Sonoma Valley Wildlife Corridor contains open land in an otherwise highly utilized valley between two mountain chains, making it a critical location for wildlife movement.

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Because it was identified as an important state and regional linkage (Spencer et al. 2010, Bay Area Open Space Council 2011, Fig. 1-B), the Sonoma Land Trust took the lead to permanently preserve it. They partnered with scientists to document the corridor's significance for daily wildlife movement and climate resilience. The Land Trust took advantage of three main opportunities to develop a comprehensive implementation strategy: interest by the local community in wildlife, the positive relationship between landowners and the Trust, and the upcoming repurposing of a large publicly owned land parcel in the critical linkage (Fig 1-C). Continued monitoring by the Trust and their volunteers (Fig. 1-F) is valuable not just for adaptive planning and management but also to maintain interest from the public. Communication with the public and key participating landowners resulted in a shared vision, which is resulting in the preservation of the corridor through land protection and management.

Desert Renewable Energy Conservation Plan

The Desert Renewable Energy Conservation Plan (DRECP) was created out of the need to balance development of renewable energy projects on public lands with natural resource conservation. Partners from state and federal agencies, industry, and conservation organizations (Fig. 1-A) developed a vision of a permeable landscape that also accommodates new renewable energy projects. Because renewable energy development has been a political and economic priority in California, the Plan received extensive political and financial support. Due to ambitious ecological objectives, including the recovery of the endangered Desert tortoise (*Gopherus agassizii*) and increased ecosystem resilience, considerable data acquisition, mapping, and species and climate modeling (Fig. 1-B) was conducted, however integrating biological data collected at different scales was challenging (Fig. 1-C). The high-level political support presented an opportunity for developing land use

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allocation prescriptions to maintain a connected landscape. Primary challenges were balancing energy development and conservation needs, the large extent of the project area, and the resulting complexity of the aligning stakeholder objectives. Whereas the previous examples considered individual corridors, the large landscape of the DRECP required a different implementation strategy (Fig. 1-D). The project resulted in land use allocations that promote either natural resource conservation or energy development. Ongoing development of management guidelines, habitat restoration, and private land planning will be completed in future phases. The strategy to achieving a permeable landscape acceptable to the large number of stakeholders with widely varying perspectives was to base the effort squarely on complying with existing state and federal conservation regulations and employing extensive amounts of field and spatial data. Here we see the importance of regulations for enacting on-the-ground solutions.

Conclusion

While the process of connectivity implementation from planning to monitoring outlined in the framework appears linear, many of the activities overlap in time, there are feedback loops between the major actions, with adjustments needed to accommodate opportunities or challenges that arise. The different categories of opportunities, such as community visioning, communication, partnerships, and laws and regulations, are elements that are needed to fill the planning-implementation space. While natural science is necessary for effective corridor planning, these social processes may be as important for project success and argues for increased input from social scientists to inform conservation planning and implementation. By outlining the components important for implementation and pointing out their relationships the framework effectively fills the planning-implementation space. When operating in this space, interviewees emphasized that flexibility, creativity, transparency, and

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persistence are necessary for success in accomplishing on-the-ground connectivity conservation.

While detailed implementation recommendations need to be project-specific, our research revealed overarching recommendations that are relevant in most contexts (Table 2). We hope that these and other suggestions discussed in this study will ensure that a large number of existing planning efforts can be translated into habitat connectivity conservation and restoration.

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Table 1. Case studies illustrating a framework for connectivity implementation.

	Hwy 17, Santa Cruz County	Sonoma Valley Wildlife Corridor	Desert Renewable Energy Conservation Plan
Sources	Nancy Siepel (Caltrans) http://pathwaysforwildlife.com/hwy_17_wildlife_connectivity_improvement_project	Bob Neale, Tony Nelson (Sonoma Land Trust) https://sonomalandtrust.org/pdf/WildlifeCorridorOnline.pdf	Jim Weigand, Vicki Campbell (Bureau of Land Management) http://www.drecp.org/

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Objective	Create a safe passageway across a busy, congested 4-lane highway that poses a barrier to wildlife movement.	Maintain and restore a regional scale wildlife corridor across Sonoma Valley, California, that encompasses approximately 10,000 acres, and stretches from the top of Sonoma Mountain across Sonoma Creek and the valley floor to the Mayacamas Mountains to the east. The Corridor is part of a much larger network of proposed linkages connecting habitats from the coast through the coastal mountains providing a vital connection for wildlife movement within the northern San Francisco Bay Area.	Prescribe land use allocations on public land in the desert region of California, aiming to balance natural resource conservation including landscape connectivity with renewable energy development. For private lands, the

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			plan provides a vision for biological conservation to inform conservation planning and investments.
Partners	Land Trust of Santa Cruz County, Santa Cruz County Regional Transportation Commission, California Department of Transportation, California Department of Fish & Wildlife, University of California, Santa Cruz Puma Project	Sonoma Land Trust, other local conservation organizations, county and state parks, landowners, academia	Main planning agencies: California Energy Commission, California Department of Fish and

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			Wildlife, Bureau of Land Managem ent, United States Fish and Wildlife Service; other state and federal agencies, tribal and local governme nts, NGOs, private entities
Intend ed conser	• Provide connectivity for multiple species to prevent genetic isolation and population fragmentation	• Facilitate wildlife movement and range shifts under climate	• La ndscap

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vation outcomes	change	e-scale system of connected conservation areas • Ecologically functional natural communities • Conservation of viable self-sustaini

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			ng populations of focal species
Planning: Data and analysis	• Camera trap data • Mountain lion (*Puma concolor*) telemetry data • Road kill data • Regional wildlife linkage models	• Wildlife camera grids and underpass monitoring and analysis of species detection rates • Parcel scale mapping • Landscape permeability analysis • Climate analysis comparing maximum summer and winter minimum temperatures between corridor termini	• Resource distribution in the planning area • Data on species occurrences, movement, dispersal, and population structur

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e and trends

- Species habitat models
- Maps of natural communities
- Expert knowledge of the resources
- Climate modeling and climate change resiliency plans

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Opportunities	• Public-private partnership • Media campaign to generate public support • Land trust engaging lobbyists to generate agency support • Pilot agreement created advanced mitigation credits for wildlife connectivity • Sufficient biological data for project planning • Safety concern for humans (agency desire to decrease animal-car collisions)	• Interest by locals in wildlife • Long-standing positive relationship between partners • Large parcel of public hospital land closing and up for repurposing	• Politically motivated integration of sensitive biological resource conservation with renewable energy development • High-level (Secret

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			ary of Interior, California Governor) political support • Financial and staff support from federal and state agencies
Challenges	• Funding for construction of crossing structure	• Lack of funding for stewardship and cost	• High level of

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• Lack of precedence for funding model	sharing with landowners to improve habitat condition and corridor function • Private and public land (state hospital) in corridor threatened by intensive agricultural and residential development • Busy roadways and increasing recreation pressure • Lack of mechanisms and opportunities for organizations to work together • Initial lack of species presence and movement data, vegetation maps • Uncertainty of climate predictions (especially precipitation) and lack of climate predictions at preserve scale	project complexity • Very large number of stakeholders • Integrating biological data collected at different scales • Ensuring that most of

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		• Not clear how to measure success for the project given limited capacity and funding	the sensitive species in the desert were considered • Staff inexperience with large project development
Implementation Tools	• Crossing structures • Conservation easements	• Public engagement and development of a shared vision • Conservation easements in the corridor • Removal and mitigation of barriers to animal	• Land use allocation • Required

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		movement • Riparian area restoration • Land management for permeability • Sharing best management practices with landowners • Manage recreation to minimize impacts to wildlife	management action (habitat restoration; land acquisition; mitigation, avoidance, and minimization action)
Monitoring and Evaluation	• Plans to monitor underpass effectiveness with camera traps, telemetry studies, and roadkill surveys	• Wildlife monitoring	• Includes guidelines for monitoring and adaptive

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Table 2. Overarching recommendations and best practices for governments, public agencies, and conservation organizations that are relevant in most implementation contexts. Detailed recommendations necessarily need to be project specific as the socio-ecological context affects the whole process of connectivity implementation.

Recommendation	**Justification**
Create clear regulations and policies for public agencies.	Important for spurring government agencies to address connectivity conservation.
Create voluntary incentive programs for private landowners.	Private landowners likely respond better to incentive programs than to regulations.
Offer incentives to diversify agricultural lands and cityscape.	This would increase general landscape permeability.
Use zoning with incentives to promote land conservation.	Especially in landscapes where development is sprawling, zoning can keep key areas open for wildlife, averting the need to purchase land for connectivity conservation in the future.
Create connectivity-specific funding sources.	This would enable connectivity projects that may otherwise fall through the cracks, e.g. because conservation legislation focuses on endangered species, which may not be present in all corridors. It would also

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	mainstream connectivity conservation, which is necessary for rapid, landscape-wide implementation.
Use the level of threat of land use conversion to development and intensive agriculture as a basis for identifying the most critical locations for corridors.	Focus connectivity conservation in high-risk areas.
Avoid planning at parcel scale in private lands without landowner engagement.	Landowners will often feel targeted by what are perceived as new regulations or restrictions on rights.
Land acquisition should be phased to complete a minimum viable linkage.	If linkage implementation involves multiple private properties this strategy ensures a continuous corridor that can be widened with time to allow for redundancy and possibly greater functionality into the future.
Set clearly-defined spatial priorities and implementation timelines where possible, and appropriate.	This ensures that connectivity goals are being met.
Run state/country-wide and regional public campaigns.	Public outreach galvanizes support and participation.
Wildlife agencies should coordinate and facilitate the collection of solid biological baseline data.	These data are vital for justifying corridor projects to stakeholders and the public, as well as for determining the best location for a corridor in priority connectivity areas.
Offer training for conservation practitioners on how to interpret and use	This ensures that science is used to maximum benefit.

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	connectivity data.
Focus connectivity programs within regions with similar ecological and social attributes.	Implementing connectivity in ecologically and socially similar regions may be more successful than spanning diverse areas.

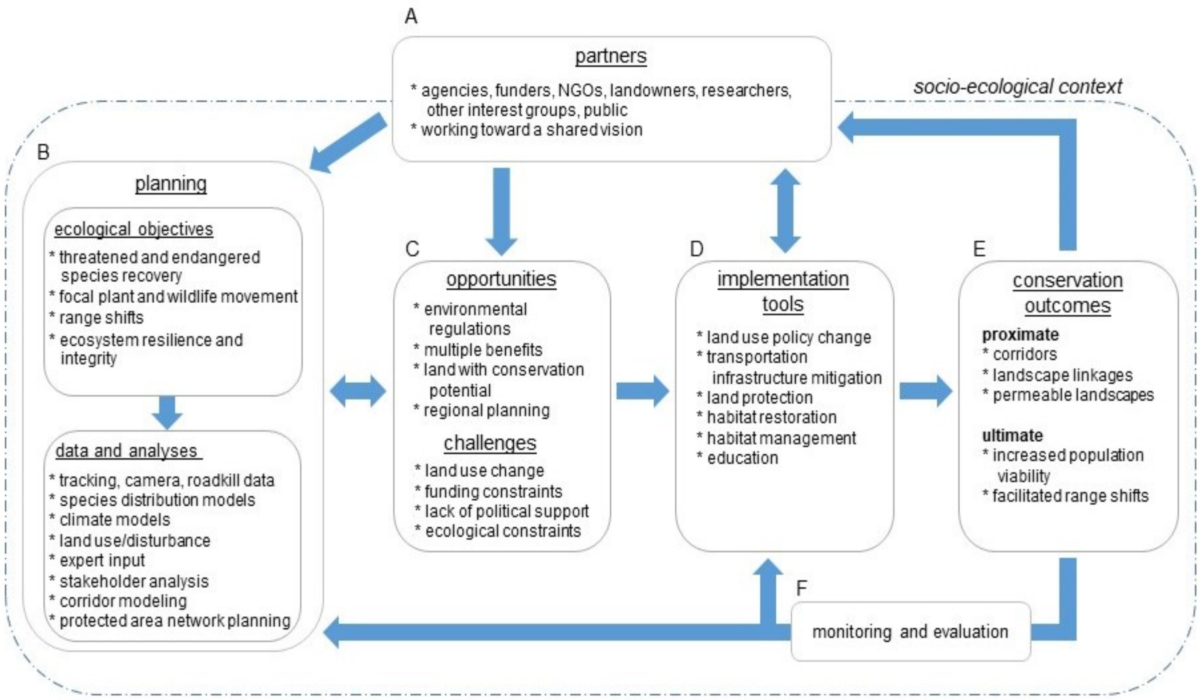

Figure 1. This framework for connectivity implementation includes: (A) Early partner engagement; (B) clear ecological objectives that drive data type and analysis; (C) opportunities and challenges that may advance or hinder implementation and should be addressed in the planning phase; (D) strategies to overcome to overcome challenges and ensure success; and (E) resulting outcomes that increase connectivity and foster continued conservation by the partners; and finally (F) monitoring and project evaluation for adaptive management.

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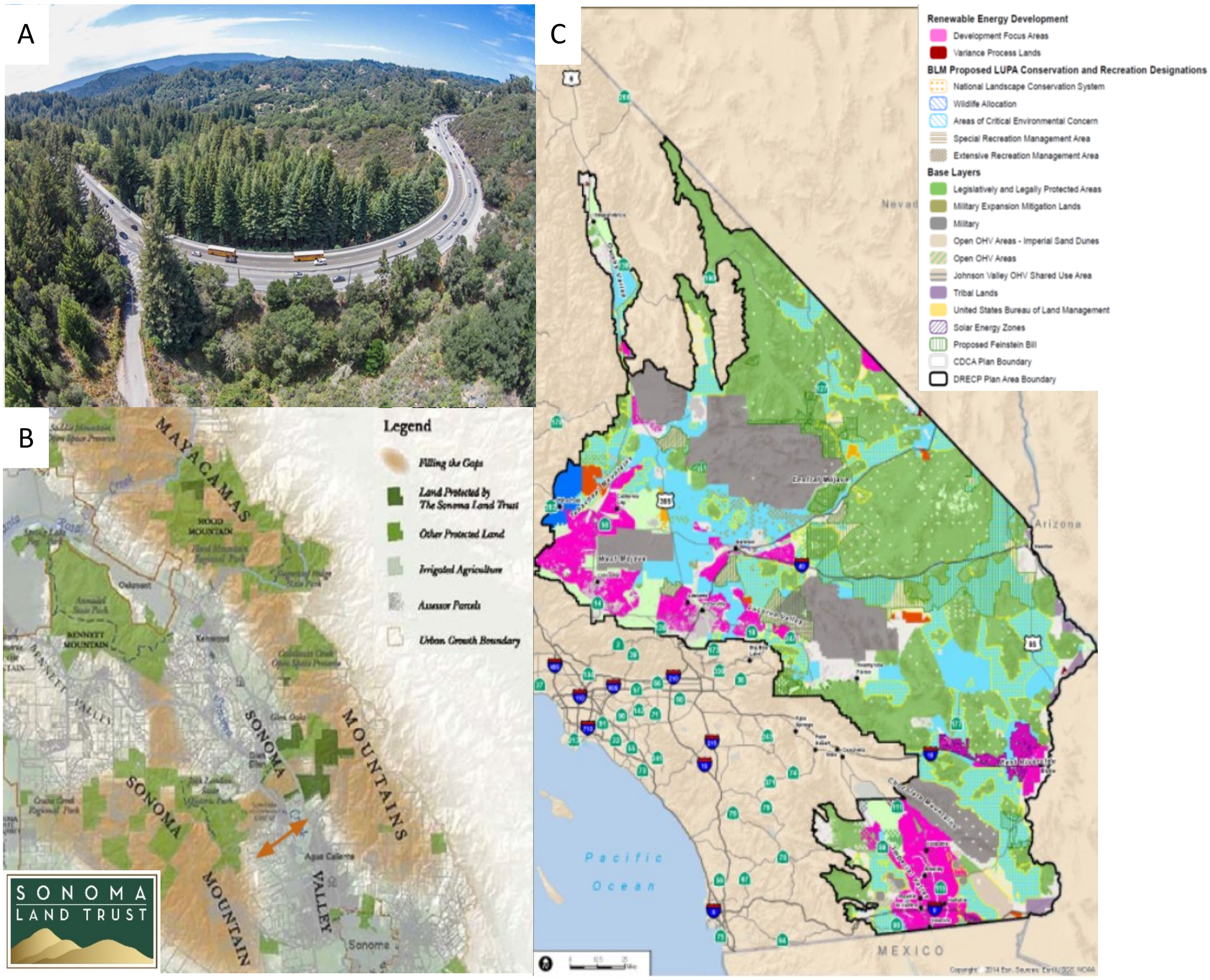

Figure 2. The location for the planned wildlife crossing structure under Highway 17 in Santa Cruz County, California (A); the Sonoma Valley wildlife landscape linkage just above the orange arrow in Sonoma County, California (B); the zoning map of the Desert Renewable Energy Conservation Plan, in southeastern California. Source: U.S. Bureau of Land Management 2016. Record of Decision. BLM/CA/PL-2016/03+1793+8321 (C).

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