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A riparian conservation network for ecological resilience

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ABSTRACT

A crucial gap exists between the static nature of the United States' existing protected areas and the dynamic impacts of 21st century stressors, such as habitat loss and fragmentation and climate change. Connectivity is a valuable element for bridging that gap and building the ecological resilience of existing protected areas. However, creating terrestrial connectivity by designing individual migration corridors across fragmented landscapes is arguably untenable at a national scale. We explore the potential for use of riverine corridors in a Riparian Connectivity Network (RCN) as a potential contributor to a more resilient network of protected areas. There is ample scientific support for the conservation value of riparian areas, including their habitat, their potential to connect environments, and their ecosystem services. Our spatial analysis suggests that they could connect protected areas and have a higher rate of conservation management than terrestrial lands. Our results illustrate that the spatial backbone for an RCN is already in place, and existing policies favor riparian area protection. Furthermore, existing legal and regulatory goals may be better served if governance requirements and incentives are aligned with conservation efforts focused on riparian connectivity, as part of a larger landscape connectivity strategy. While much research on the effectiveness of riparian corridors remains to be done, the RCN concept provides a way to improve connectivity among currently protected areas. With focused attention, increased institutional collaboration, and improved incentives, these pieces could coalesce into a network of areas for biological conservation.

1. Introduction

The key challenge for biodiversity conservation in the Anthropocene is counteracting the accelerating rate of species extinctions resulting from habitat loss and fragmentation, climate change, and invasive species (Baron et al., 2009; Griffith et al., 2009). In response to this challenge, reconstructing connectivity between protected areas is an important element of *conservation infrastructure*, defined as landscape attributes resulting from actions or policies designed to foster biological conservation, such as protected areas, conservation easements, and so forth (Hannah et al., 2002).

In the United States, national parks, wilderness areas, and wildlife refuges were set aside primarily to preserve scenic geological wonders, migratory birds, and game species, and now form the core of the de facto public land system. Conserving biodiversity was not the primary consideration in selection and siting of this system (Aycrigg et al., 2013). The administrative boundaries of these areas were often located to avoid existing development rather than for ecological reasons (e.g., Wilderness Act, 16 CUS. §§ 1131–1136). In addition, the majority of these areas were protected before ecological science recognized the importance of large-scale ecological processes, such as migrations, metapopulation dynamics, and gene flow (Mills, 2012; Minor and Lookingbill, 2010). It is only recently that attention has been focused on securing or restoring areas that provide structural and functional connectivity between protected lands.

Concepts of social–ecological resilience indicate that governance and conservation actions need to increase a system's ability to respond to natural and human-induced perturbations (sensu Biggs et al., 2012). One approach is to increase connectivity (Bengtsson et al., 2003; Elmqvist et al., 2003). Developing spatially networked connectivity between existing protected areas enables species to move more readily in response to changing environmental conditions (Johnston et al., 2013). This spatial aspect allows species and communities to survive

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perturbations by avoiding them or resisting them, and responding afterwards by recolonizing. The recolonized communities might be similar to pre-disturbance ones or entirely transformed (Bengtsson et al., 2003). For example, connectivity fosters resilience to directional climate change (press disturbance) by increasing the potential for species' redistribution into climatically suitable areas (Crimmins et al., 2011). Habitat connectivity can also contribute to escape from or recolonization of occupied areas following events such as wildfires or floods (pulse disturbance) (Elmqvist et al., 2003).

If the goal, therefore, is to increase resilience through connectivity, riparian networks should be an important component because they connect headwaters to lowlands in a structured, complex, and dendritic pattern (Beier, 2012). Connecting riparian networks could complement the existing protected landscape in which higher elevation areas are typically emphasized and lowlands under-represented (Noss et al., 1996). Although data on the degree to which riparian areas serve as corridors for species movement is limited, there is evidence that even an anthropogenically disturbed riparian corridor has the potential to replicate many of the functions of an undisturbed one (Hilty and Merenlender, 2004). For example, Hilty and Merenlender (2004) found that, although native mammalian predators (e.g., coyote, *Canis latrans*; raccoon, *Procyon lotor*) preferred wider riparian corridors, they nonetheless used narrower, human-disturbed corridors in agricultural landscapes. In addition, wildlife movement through road underpasses associated with rivers and streams is well documented (Clevenger and Waltho, 2000; Santos et al., 2011). Although disturbed riparian corridors are not the equivalent of undisturbed ones (Battin, 2004), this body of literature suggests that species will use disturbed riparian corridors when undisturbed ones do not exist.

Riparian areas can play an important role in providing habitat connectivity for many species in fragmented or heterogeneous landscapes (Hilty and Merenlender, 2004). These areas typically support assemblages of hydrophilic organisms and are characterized by the influence of periodic water inundation and the exchange of materials and energy with the surrounding ecosystems, namely the stream and upland areas (Naiman and Decamps, 1997). Although riparian areas typically are not large, they do offer extensive linear networks that allow many species to move through otherwise inhospitable areas (Rouquette et al., 2013; Tremblay and St. Clair, 2011). The role that riparian areas play as corridors between and among protected areas is poorly documented, particularly with respect to what characteristics promote connectivity for which species. The use of riparian areas for movement is species-specific (Gilbert-Norton et al., 2010; Lees and Peres, 2008). Nonetheless, multiple terrestrial species rely on riparian areas at some point in their life history (Naiman and Decamps, 1997), most commonly for migration through human-modified landscapes (Santos et al., 2011). Additionally, a variety of species use riparian corridors for access to water, escape from predators, cover, food, nesting habitat, and dispersal or movement between habitat patches (Brost and Beier, 2012).

Rebuilding habitat connectivity with riparian networks is no panacea, particularly in fragmented and altered landscapes (Goetz et al., 2009). The condition of riparian areas is highly variable and many riparian areas will likely require restoration before they serve as functional corridors (Theobald et al., 2010). However, even small sections of degraded riparian areas can act as chokepoints by limiting larger-scale connectivity and some animals might not use intact riparian areas surrounded by human structures and activity. It is yet unclear what buffer width provides connectivity for the widest breadth of species. Conversely, increased connectivity can have negative ecological influences (Simberloff et al., 1992). Regardless, although connectivity might facilitate the spread of invasive species and disease or increased disturbance, improved habitat connectivity is a net positive conservation outcome (Hannah et al., 2002; Shafer, 2014). Moreover, Haddad et al. (2014) found no broad evidence to support the possible undesirable side-effects of increased habitat connectivity and further suggested that wider corridors and softer corridor edges could ameliorate potential negative impacts.

Restoration of river and riparian areas benefits not only species conservation, but also water quality and esthetics (Bernhardt et al., 2005). Restoration actions, including reactivating floodplains, build upon existing efforts that protect valuable ecosystem services, such as water filtration, recreation, and flood control (Brauman et al., 2007; Fremier et al., 2013). Although they are often degraded (Theobald et al., 2010), riparian forests account for much of the remnant forests on numerous landscapes (Lees and Peres, 2008). Increased conservation efforts in these areas may also increase the ability of species to move through intensively managed landscapes. Restoring and protecting riparian areas thus can serve human needs while also providing a connected riparian connectivity network.

Furthermore, a riparian connectivity network could take advantage of existing policy mechanisms. That is, a project to establish such a network could leverage an existing suite of administrative, state, and federal policies that already protect riparian areas and thereby avoid the political battles that would be involved in enacting new laws (Citron, 2010; Lacey, 1996; Thompson, 2004). A key challenge, therefore, will be to coordinate restoration actions, conservation easements, and other conservation-related actions associated with existing policies to foster large-scale habitat connectivity at a continental scale.

We analyzed the current pattern of the protected area system in relation to riparian management on public and private lands for the contiguous United States (lower 48 states) to examine the practical potential of implementing a national Riparian Connectivity Network (RCN) that could coordinate protection, restoration, and management of riparian areas to build habitat connectivity among existing protected areas. We applied a coarse-scale spatial analysis to quantify the potential riparian linkages between existing protected lands. Recognizing that even an ideal physical solution is promising only to the degree that it can be implemented, we developed the concept of an RCN by combining initial evidence for its geospatial and ecological feasibility with a conceptual analysis of its practical and legal potential for implementation.

2. Materials and methods

To assess the biophysical potential of an RCN, we quantified the type, amount, and location of stream/riparian protection for continental US outside of Alaska using available spatial data. We employed a geographic information system (GIS) to analyze spatial and jurisdictional patterns in riparian management (ArcGIS version 10, ESRI 2011). We addressed four questions regarding distribution, area, and context of existing protected areas and their relationship to river corridors: 1) How many of the existing protected areas are connected to one or more protected areas via a river corridor? 2) What percentage of riparian corridors is buffered by protected areas? 3) What is the spatial pattern of riparian area protection across the lower 48 states? Finally, 4) are conservation easements spatially associated with riparian areas?

2.1. Geospatial data

We analyzed three publicly available spatial databases: 1) Protected Areas Database of the US (PAD-US); 2) National Conservation Easement Database (NCED); and 3) National Hydrography Database (NHD*plus*). PAD-US represents public land ownership and conservation lands, including privately owned protected areas (PADUS version 1.2 USGS-GAP accessed 2011). The native resolution of PAD-US is variable because data are provided by multiple agencies with a defined standard of 1:100,000 spatial accuracy (USGS-GAP, 2013). Lands are assigned conservation status codes (i.e., GAP Status codes) that both denote the level of biodiversity preservation and indicate other natural, recreational, and cultural uses (See Table 1 for code descriptions).