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Where and why does restoration happen? Ecological and sociopolitical influences on stream restoration in coastal California

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ABSTRACT

The distribution of conservation effort on the landscape is affected by both ecological and social priorities and constraints. Together these influences can result in bias towards certain types of ecological or human communities. We evaluate the distribution of restoration projects on the California Central Coast, USA, to evaluate sociopolitical and biophysical influences on the type and distribution of one type of conservation effort. We compiled data on 699 sites with publicly funded stream restoration and management projects completed in the past 30 years and the biophysical and sociopolitical characteristics of the 310 sub-catchments in our study area. Our database contains three categories of stream projects: ecological restoration to benefit natural ecosystems, human-oriented projects to enhance ecosystem services, and data collection projects for planning and monitoring. Both ecological and human-oriented restoration efforts were clustered near the coastline. Stream activities of all kinds were highest in sub-catchments with water quality impairment, high population density, high pro-environmental voting, and a highly educated, wealthy, non-Hispanic white population. Ecological restoration and data collection were also greater in catchments with higher native fish richness. Our findings indicate that restoration activity is aligned with, and perhaps responding to, ecological need, and that restoration efforts are concentrated near human population centers and restoration organizations. Disparities in conservation effort by income, race, and education are concerning and should be evaluated in more depth and in other regions.

1. Introduction

As humans degrade natural ecosystems, conservation has become a large and growing need. The distribution of ecological management effort across a landscape affects both ecological and human communities. Ecosystems receiving more protection or restoration may regain lost resilience and ecosystem function, experience enhanced connectivity, and support a broader host of species (Ruiz-Jaen and Aide, 2005; Benayas et al., 2009). Human communities situated near high-quality natural areas or restoration projects may experience enhanced health and recreational opportunities (Brancalion et al., 2013; Wolch et al., 2014), protection from erosion and floods (Clewell and Aronson, 2006; Nilsson et al., 2018), employment opportunities (BenDor et al., 2015), and connection to nature and community (Light, 2006; Moran, 2010; Egan et al., 2011; although see e.g., DeFries et al., 2007).

In recent years, tools and frameworks have proliferated to assist managers and funders in selecting appropriate sites and projects to maximize (largely ecological) benefits given limited conservation budgets (Norton et al., 2009; Jellinek, 2017). Such tools often prioritize conservation in sites with high ecological value or condition, such as regional reference sites or refuges for endemic or endangered species, in part because agencies often have regulatory mandates to protect these areas. In contrast, restoration projects seeking to maximize benefit per dollar spent might prioritize sites unlikely to recover unassisted (Fullerton et al., 2006), or highly impaired sites that negatively impact the surroundings (e.g. through spreading invasive species or changing the disturbance regime) (Leite et al., 2013).

The literature on prioritization tools has a largely normative focus; it provides guidance for where conservation projects *should* be located, usually from a purely ecological perspective (e.g., Moilanen et al., 2009), and pays little attention to the empirical outcomes, i.e. where projects *are* located in practice. The actual locations, however, may differ from the normative guidance. First, decision-makers may be motivated by the potential for social benefit, for example through ecosystem service enhancement or protection (Chan et al., 2006; Standish et al., 2012). Researchers traditionally have not emphasized socioeconomic benefits of restoration (Aronson et al., 2010; Wortley et al., 2013), although these can be substantial (Hillman, 2004;

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Millennium Ecosystem Assessment, 2005; BenDor et al., 2015). Urban parks and urban stream restoration are both examples of ecological management strategies often undertaken for social benefit (Cockerill and Anderson, 2014; Flies et al., 2017). In other cases, systems with high ecological value are prioritized for conservation due to co-benefits such as visitation, recreational uses such as hunting or fishing, or improved municipal water quality (e.g. Turner and Daily, 2007).

Second, the spatial distribution of conservation efforts and benefits may be influenced by socioeconomic and political factors. Conservation may be more feasible in locations with high public interest in environmental issues if this results in the presence of more environmental organizations, funding opportunities, and access to private lands (Christian-Smith and Merenlender, 2010; Langridge, 2016). Similarly, wealthy pro-environmental communities may mobilize to advocate for their communities, resulting in capture of a greater share of regional or statewide conservation budgets (Mohai et al., 2009). Indeed, studies of the distribution of both urban greening and wetland mitigation projects have found uneven distribution across socioeconomic groups (Ruhl and Salzman, 2006; BenDor et al., 2008; Stewart et al., 2014). More broadly, policy making, at least in the United States, often reflects the preference of economic elites rather than the population more broadly (Bartels, 2008; Gilens and Page, 2014).

Finally, availability of funding may constrain the types of projects that are accomplished in an area or the choice of project location. Funding may promote a particular goal (e.g., invasive species management, human access, endangered species protection), and may also be restricted to certain locations.

To explore influences on the allocation of conservation effort, we focused on the regional-scale distribution of restoration projects in relation to ecological values and human communities. Restoration is an intensive and frequently costly type of ecological management: it can involve a transformation of the ecological community through the addition and removal of species or barriers to connectivity, and can have substantial impacts on human communities (Suding et al., 2015). A regional analysis allows us to compare priorities across many different land use types and human communities while maintaining the ability to perform a fine-grain analysis of factors potentially influencing decision-making. Analyzing the types of locations that currently receive restoration effort can reveal whether certain types of ecosystems or human communities receive disproportionate attention.

Streams present an excellent case study for questions about restoration. Streams are a particularly important ecosystem type for considering distribution of effort because their sensitivity to human activities (e.g., water diversions, land use change) results in widespread need for active stream management and restoration. In addition, due to their special protection under the US Clean Water Act, stream impairment is unusually well documented and regulated, and streams are well-mapped compared to other ecosystem types. Despite these features, patterns and drivers of stream restoration effort are poorly quantified (e.g. Bernhardt et al., 2005). Previous efforts have quantified ecological and management aspects of stream restoration, focusing on types of restoration activity (Bernhardt et al., 2005; Kondolf et al., 2007; Christian-Smith and Merenlender, 2010), motivations and land use context (Bernhardt et al., 2007; Moran, 2010), or match between restoration and actions called for by endangered species recovery plans (Barnas et al., 2015). However, to our knowledge the relationship between the spatial distribution of effort and both ecological and sociopolitical patterns has not been evaluated.

Whether restoration projects are effective in achieving their conservation goals is a question beyond the scope of this paper (see Suding, 2011; Maron et al., 2012; Jones et al., 2018). Indeed, research to date has found high uncertainty among outcomes for stream-based projects (Bernhardt and Palmer, 2011; Wohl et al., 2015). However, regardless of ecological outcomes, the spatial distribution of restoration projects is intrinsically important as a reflection of intent and resource allocation.

We selected the California Central Coast region, USA for our study for its high biodiversity and unusual variety of biophysical conditions, land use types, and human communities. Within the California Central Coast, we compared the distributions of stream restoration projects focused on ecological goals, such as fish habitat, water quality, or riparian condition; projects focused on human well-being, such as flood control and access; and projects collecting pre- or post-project data. We analyze how restoration effort varied spatially using biophysical and sociopolitical factors as indicators of both intended priorities and unintended biases affecting restoration effort. We ask: which natural and human communities benefit from restoration efforts? What implicit priorities can we detect in the distribution of projects?

2. Methods

2.1. Study design

We mapped stream restoration and management projects within the five counties of the California Central Coast (Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, and San Benito). The study area extends 500 km along the coast and 60 km inland. California is among the top three regions in the United States for density of stream restoration projects (Bernhardt et al., 2005), and the Central Coast has active local agencies and a robust monitoring program documenting the condition of streams. The Central Coast ranges in elevation from sea level to 1700 m, and includes both the foggy, redwood-covered Santa Cruz Mountains and the dry Carrizo Plain. It is largely rural and agricultural (including the highly productive Salinas Valley) but contains several large urban centers, including Monterey, Santa Cruz, and Santa Barbara.

We measured restoration effort as 1) number of restoration project sites and 2) the amount of public restoration spending occurring within each catchment unit (defined here as the 12-digit Hydrologic Unit Code or HUC, the smallest nationally defined hydrologic unit). The study area contains 310 catchment units; dividing the region in this way provided a natural unit of analysis. Catchment units within the study area have mean area of 85 km^2 (sd = 35) and 144 stream km (sd = 71). We clipped the study area to match California Regional Water Quality Control Board Region 3, which administers much of the funding, monitoring, and regulation for the region (Central Coast Regional Water Quality Control Board et al., 2016); this resulted in the exclusion of eight catchment units in eastern San Benito County. Our study also excludes the five easternmost catchment units of San Luis Obispo County and the Channel Islands because key datasets lacked information for these areas.

2.2. Data collection

We compiled databases documenting publicly funded restoration over the past 30 years (Table A1). We focus on publicly funded projects because public funds support over 80% of all stream restoration in the US (Bernhardt et al., 2007) and were more consistently tracked across jurisdictions. We identified potential databases using personal contacts and internet searches.

We used a modified version of the National River Restoration Science Synthesis classification system (Bernhardt et al., 2005) to classify each project by restoration type. In our analysis, we combined several NRRSS categories and added categories describing stream management for human benefit (Table 1). If multiple activities were described, we assigned the project to the activity that appeared to be the primary motivation based on the project title and brief description (e.g., a project to control bank erosion using riprap and the restoration of native vegetation would be coded as bank stabilization). Throughout, we refer to all entries in our final database as “restoration sites.” On-the-ground projects with ecological goals are classified as “ecological restoration,” projects undertaken for human benefit are “human-oriented”, and projects focusing on planning, research, or monitoring are