ECOLOGY

Synthesizing U.S. River Restoration Efforts

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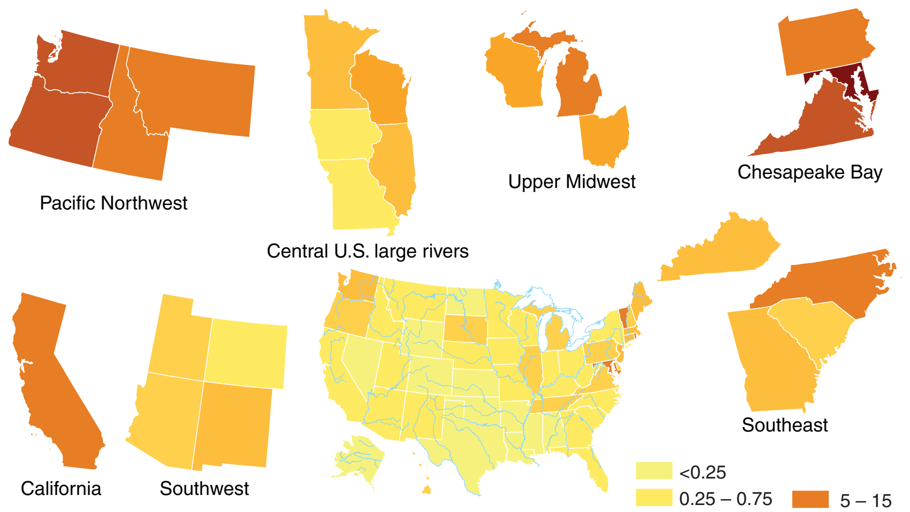
The importance of rivers and streams for fresh water, food, and recreation is well known, yet there is increasing evidence that degradation of running waters is at an all-time high (*1*). More than one-third of the rivers in the United States are listed as impaired or polluted (*2*), and freshwater withdrawals in some regions are so extreme that some major rivers no longer flow to the sea year round (*3*). Extinction rates of freshwater fauna are five times that for terrestrial biota (*4*, *5*). Fortunately, stream and river restoration can lead to species recovery, improved inland and coastal water quality, and new areas for wildlife habitat and recreational activities (*6*–*11*).

River restoration has become a highly profitable business (*12*, *13*) and will play an increasing role in environmental management and policy decisions (*7*). A few high-profile and large restoration projects such as those on the Kissimmee River (*11*, *14*) and the Grand Canyon (*15*, *16*) are well documented. However, most restoration projects are small scale (implemented on less than 1 km of stream length), and information on their implementation and outcome is not readily accessible. This prompted us to build a database of river restoration across the United States with the goal of determining the common elements of successful projects. We found that existing restoration databases are highly fragmented and often rely on ad hoc or volunteer data entry. Thus, we developed methods for the unbiased collection and cataloging of river and stream restoration projects. Here, we report a synthesis of information on 37,099 projects in the National River Restoration Science Synthesis (NRRSS) database.

The NRRSS database includes all stream and river restoration projects present in national databases as of July 2004, as well as a large sample of river and stream restoration projects from seven geographic regions (see figure, below) [(*17*) part a]. Because we wanted to document how restoration dollars and efforts were allocated, we did not limit data collection to projects that fit our definition of restoration. No judgments were made of the validity of the terms "stream restoration" or "project." Use of national coverage data sources] (*17*) part b] ensured inclusion of projects from all 50 states. For the seven specific regions, we also collected information on all restoration projects for which we could obtain data, regardless of project size, restoration method, implementer, or perceived success or failure of the project. We identified a priori 13 categories of restoration and classified each project according to its stated goal [see table, page 637 and (*17*) part c].

The number of river restoration projects increased exponentially during the last decade, paralleling the increase in news media and scientific reports [fig. S1 (*17*) part d]. However, restoration efforts varied across geographic regions. Most projects (88%) are from the Pacific Northwest, the Chesapeake Bay watershed, or California (see figure, below). Data from national coverage sources [(*17*) part b] made up <8% of projects in the NRRSS database. Thus, while federal funding supports some tracking efforts, national restoration databases are not tracking the majority of projects and lack information on the regional differences in expenditures and effort found with our approach.

The most commonly stated goals for river restoration in the United States are (i) to enhance water quality, (ii) to manage riparian zones, (iii) to improve in-stream habitat, (iv) for fish passage, and (v) for bank stabilization (see figure, page 637). Projects with these goals are typically small in scale with median costs of <$45K (see table, page 637). A large proportion of restoration dollars are spent on fewer, more expensive projects aimed at reconnecting floodplains, modifying flows, improving aesthetics or recreation, and reconfiguring river and stream channels (see figure, page 637). Of the projects in our database, 20% had no listed goals; in many cases, descriptions were too limited to determine whether projects were undertaken to restore stream ecosystems or were merely river manipulation projects (e.g., bank stabilization) (*18*).



Project density (no. of projects per 1000 river km) from national coverage databases only versus in-depth regional project record summaries (all data sources) [table S1 (*17*) part h].

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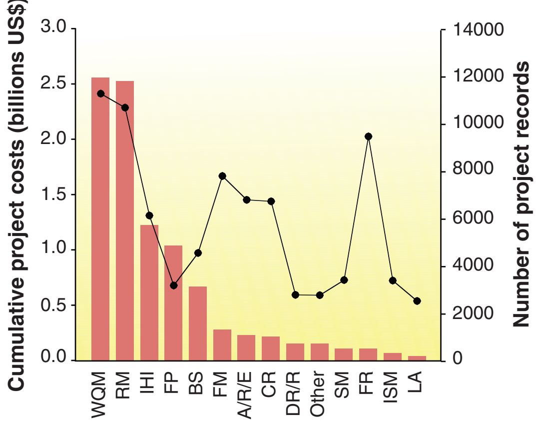

Distribution of projects within each restoration goal category. Abbreviations of categories are in table below.

Only 58% of the project records used to populate our database had information on project costs. For this subset, total costs came to $9.1 billion. Most of this was spent after 1990, with $7.5 billion in recorded costs from 1990 to 2003 (from the 58% reporting costs). Applying this cost estimate to the remaining ~40% of projects [(*17*) part e], and taking into account that we captured ~27% of all stream and river restoration projects in the 27 states not within one of our regional nodes [(*17*) part e], at least $14 to $15 billion has been spent on restoration of streams and rivers within the continental United States since 1990, an average of >$1 billion a year. This is probably an underestimate, because data providers reported that the costs listed in project records typically do not include matching or in-kind contributions such as agency labor. In addition, the data sources we accessed did not capture costs for the restoration of the Kissimmee River or the full costs of Glen Canyon, San Francisco Bay, Columbia, and Missouri river restoration efforts, which would add hundreds of millions to billions of dollars (*17*).

Our analysis confirms what the General Accounting Office (GAO) has suggested in recent reports to the U.S. Congress (*19*, *20*): a comprehensive assessment of restoration progress for the United States, or even for individual regions, is not possible with the "piecemeal" information currently available. We found that only 10% of project records indicated that any form of assessment or monitoring occurred. Most of these ~3700 projects were not designed to evaluate consequences of restoration activities or to disseminate monitoring results.

Monitoring and assessment varied by region: >20% of projects in the Southwest, Southeast, and Central United States had some form of monitoring, whereas only 6% of project records in the Chesapeake Bay watershed indicated that monitoring occurred (see figure, page 636). Projects with higher costs were more likely to be monitored [average costs were $1.5 ± $0.7 million (95% CI), whereas unmonitored project costs were $0.4 ± $0.08 million]. Regions with greater project density tended to have lower average project costs and reported a lower rate of monitoring. Further, differences in regional regulations are likely.

Because most project records were inadequate to extract even the most rudimentary information on project actions and outcomes, it is apparent that many opportunities to learn from successes and failures, and thus to improve future practice, are being lost. The largest and most costly programs have recognized this problem and have enacted solutions (*16*, *19*). Unfortunately, the outcomes of most of the tens of thousands of projects of small-to-modest size are currently not adequately tracked, yet cumulatively, their costs are greater, and their reach is far broader. Much greater effort is needed to gather and disseminate data on restoration methods and outcomes, particularly given the magnitude of costs. It is unrealistic to expect that every restoration project will have extensive monitoring activities, but strategic pre- and postassessments with standardized methods could enable restoration practitioners and managers to understand what types of activity are accomplishing their goals (*21*). Ensuring data compatibility in the tracking of restoration projects and the documentation of results from project evaluations are equally important. To facilitate this effort, the NRRSS database structure and schema are freely available (*22*).

MEDIAN COSTS FOR GOAL CATEGORIES

NRRSS goal category	Median cost	Examples of common restoration activities
Aesthetics/recreation/education (A/R/E)	$63,000	Cleaning (e.g., trash removal)
Bank stabilization (BS)	$42,000	Revegetation, bank grading
Channel reconfiguration (CR)	$120,000	Bank or channel reshaping
Dam removal/retrofit (DR/R)	$98,000	Revegetation
Fish passage (FP)	$30,000	Fish ladders installed
Floodplain reconnection (FR)	$207,000	Bank or channel reshaping
Flow modification (FM)	$198,000	Flow regime enhancement
Instream habitat improvement (IHI)	$20,000	Boulders/woody debris added
Instream species management (ISM)	$77,000	Native species reintroduction
Land acquisition (LA)	$812,000	
Riparian management (RM)	$15,000	Livestock exclusion
Stormwater management (SM)	$180,000	Wetland construction
Water quality management (WQM)	$19,000	Riparian buffer creation/maintenance

Median costs for goal categories.

References and Notes

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