Two Decades of River Restoration in California: What Can We Learn?

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Abstract

As part of the National River Restoration Science Synthesis (NRRSS), we developed a summary database of 4,023 stream restoration projects built in California since 1980, from which we randomly selected 44 records for in-depth interviews with project managers. Despite substantial difficulties in gathering the data, we were able to draw conclusions about current design, implementation, monitoring, and evaluation practices used in California projects and compare them with national trends. Although more than half of the projects for which we conducted interviews were located in watersheds for which a management or assessment plan had been prepared, these plans had a limited impact on site selection. We also found that the state lacks a consistent framework for design, monitoring, and reporting restoration projects, and that although monitoring is far more widespread than the information in the NRRSS summary database would suggest, there are still problems with the type, duration, and reporting of monitoring. The general lack of systematic, objective assessment of completed projects hinders the advance of restoration science.

Key words: **California, case studies, database, evaluation, monitoring, National River Restoration Science Synthesis restoration, restoration planning, river, survey.**

Introduction

As the number of river restoration projects in North America continues to grow, the Pacific coast has the largest number of projects and greatest investment overall, and California continues to be one of the most active areas for river restoration (Bernhardt et al. 2005). Restoration projects in the state span a wide range, from salmonid habitat enhancement projects (undertaken in the state since the 1930s), abundant riparian restoration projects throughout the past three decades, to more recent efforts to restore fluvial processes by modifying dam releases and augmenting sediment supply. Despite its substantial number of restoration projects, California does not have a comprehensive catalog of restoration efforts that is easily accessible by scientists, public agencies, and community groups, although database managers at state agencies are working toward this goal (e.g., California Department of Fish and Game, Information Center for the Environment). The effectiveness of the restoration investment has been largely unevaluated (cf Kleinschmidt Associates 2003). Such evaluation is essential as feedback to the adaptive management approach embraced by institutions, such as the CALFED Bay-Delta Ecosystem Restoration Program, the largest single funder of restoration in the state, with an investment over $500 million in restoration projects from 1996 to 2005. California's distinct Mediterranean climate may render river restoration approaches adopted elsewhere unsuitable (Kondolf 1998). Thus, a review of restoration projects undertaken in California to date is timely and can potentially inform future restoration efforts.

We conducted this study as part of a national effort, the National River Restoration Science Synthesis (NRRSS), using methods consistent with our NRRSS colleagues elsewhere, so that our data would contribute to a national assessment and the California results could be informed by the larger, national context (Bernhardt et al. 2007). The objectives of the study were to compile a database of restoration projects undertaken in California through 2003, and to conduct follow-up interviews with implementers of randomly selected projects. We sought to understand the type and extent of river restoration projects undertaken in the state and to gather more detailed information about current design, implementation, monitoring, and evaluation practices used in California projects to inform and improve future practice.

Methods

Detailed descriptions of database design and our data synthesis effort are available in supplemental online material to Bernhardt et al. 2005 and at our Web site: http://www.restoringrivers.org/NRRSS_Process. Here, we provide a succinct description of our methods.

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Summary Database Development

To better understand the current state of restoration in the United States, the NRRSS working group compiled a master database of river restoration projects from existing electronic databases and paper records (http://www.nrrss.nbii.gov). Database fields included project year, location, basin size, project size, intent(s), responsible agency and contact information, planning and construction dates, project activities, monitoring component, and record source. The single subjective field in the NRRSS summary database was project intent, that is, motivations, goals, or purpose. We categorized projects based on their listed intent(s) into one or more of 13 intent categories (Table 1; Bernhardt et al. 2007). This database, hereafter referred to as the summary database, was completed in 2003.

In acquiring summary data for the California node, we contacted 29 organizations involved in river restoration (Table 1). Of these contacts, eight organizations (public and private sector) contributed the majority of records in the California summary database. Each of the organizations with digital databases employed a unique structure to report records: some focused on costs or funding sources, others implementation, evaluation, or years of completion. In many existing databases, project intent divisions were not precise or consistent, making intent overlap frequent in the crossmapping process. Titles and the principal intents of a project could vary depending on the source of the information. Some organizations recorded each phase on a single site as distinct projects. In addition, many records were incomplete so that certain variables such as cost, source of funding, or monitoring information could only be extracted for a subset of projects. These and other such complications required a manual review of all accumulated records to avoid duplication. We cross-referenced the data to ensure each entry was a unique project with consistent labeling to allow for comparative analysis. After consolidating the data records, we assigned each project a single NRRSS identification number.

Two primary sources supplied 82% of entries in the California summary database. The California Habitat Restoration Project Database (CHRPD), a cooperative project of the California Department of Fish and Game, NOAA Fisheries, and the Pacific States Marine Fisheries Commission (http://www.calfish.org/uploads/CHRPD.pdf), included approximately 4,300 records, of which 1,917 were river restoration projects suitable for our database. The Natural Resources Project Inventory (NRPI), coordinated by the California Biodiversity Council and the University of California at Davis, is an online clearinghouse for maps, models, reports, and other data relevant to environmental protection in California (http://www.ice.ucdavis.edu/nrpi/). NRPI contains information on 6,000 projects, of which 1,421 were suitable for our database. We cross-checked the completeness of our database by comparing it with project information from two compilations of restoration projects for the Russian River basin compiled for a University of California dissertation by Juliet Christian-Smith (2006) and for Lower Clear Creek from the Western Shasta Resource Conservation District.

Table 1. Organizations contacted for California restoration project records.

Organization
American Rivers
Bay Area Conservation Development Commission
Bureau of Land Management
CALFED Bay-Delta Authority
California Association of Resource Conservation Districts
California Biodiversity Council[a]
California Coastal Commission
California Coastal Conservancy
California Department of Fish and Game[b]
California Department of Parks and Recreation
California Department of Transportation
California Department of Water Resources
California Environmental Protection Agency
Federal Energy Regulatory Commission
Federal Highway Administration
National Fish and Wildlife Foundation
National Oceanic and Atmospheric Administration
National Park Service
Natural Heritage Institute
Pacific States Marine Fisheries Commission[b]
Rocky Mountain Institute
Sacramento River Conservation Area
San Francisco Estuary Institute
San Jose State Department of Environmental Studies
The Nature Conservancy
United States Army Corps of Engineers
United States Fish and Wildlife Service
United States Geological Survey
University of California at Davis[a]

Organizations in bold are primary database sources.
[a] Partner for NRPI.
[b] Partner for CHRPD.

Interview Database Development

Upon completion of the summary database, we proceeded to the interview stage of the NRRSS project. The NRRSS working group developed the interview protocol and questions over the course of a year, with the input of outside natural and social scientists (Bernhardt et al. 2007). The final survey format was set in May 2004, and we obtained approval for the interview protocol from the University of California at Berkeley Committee for Protection of Human Subjects prior to conducting interviews. Most of the interview questions asked for focused, factual responses, but the last section included open-ended questions regarding lessons learned during the process of restoration (http://www.restoringrivers.org/survey).

From the Summary Database, we randomly selected projects for follow-up telephone interviews from those completed in 1996–2002, with a project contact (e.g., an individual or agency name allowing follow-up), and in one of these project intents: riparian management, water quality management, in-stream habitat improvement, or channel reconfiguration (consistent with NRRSS protocol). We used a random number generator to set the order for contacting projects meeting these conditions, and then attempted to schedule interviews with the project contacts. If the contact did not respond to multiple email and phone messages, we removed that project from the pool and moved on to the next number on the randomly generated list. If the contact responded positively, we sent a one-page summary of the interview themes and a confidentiality statement, and then scheduled a telephone interview (30–90 minutes), which we taped to facilitate data entry and quality assurance. We removed all identifying information (name of interviewee, project name, location of project) from the database as required by Institutional Review Board guidelines.

From September 2004 through October 2005, we completed a total of 44 interviews in the designated intent categories: riparian management (12), water quality management (12), in-stream habitat improvement (12), and channel reconfiguration (8). We completed interviews for only eight channel reconfiguration projects because of the small number of projects in the summary database eligible for interview. In attempting to line up interviews with our randomly selected project contacts, we abandoned 358 projects, a rate nearly three times higher than the average of other nodes in the national study. We abandoned records mostly because of unresponsive contacts and because hundreds of state-funded projects were listed in the source database under a single contract manager, making it difficult to track down the actual project lead. Other reasons for record abandonment included: the contact listed in the database had been previously interviewed, dates in the summary database were incorrect and the project had been completed outside of our survey time window, the contact information was incorrect, or the listed contact person had left the organization and no one else was qualified to discuss the project.

Results

Summary Database

The California node summary database contains 4,023 records, of which the vast majority came from the CHRPD and NRPI databases. All but one was completed after 1980. The three most common project intents were water quality (20%), riparian management (15%), and bank stabilization (13%). This is consistent with the national database, where the top three project intents are riparian management (25%), water quality (24%), and bank stabilization (12%) (Bernhardt et al. 2007) (Fig. 1). Approximately 82% of California database projects reported cost data, with expenditures totaling more than $2 billion over a 25-year time frame. The cost of individual projects ranges from $200 to $150,000,000, with a median cost of $50,257 (Fig. 2). This, too, is consistent with the results from the national database, where the cost of individual projects ranges from $1 to $426,885,000, with a median cost of $36,112.

Of more than 4,000 projects in the California summary database, 22% reported having a monitoring component (higher than the average of 10% for the national database) (Bernhardt et al. 2007). Of the projects reporting monitoring, just 11% reported the type of monitoring that occurred. Interestingly, the percentage of projects within each intent category reporting monitoring varied widely, from 1% of fish passage projects to 55% of in-stream species management projects. This variation in the California summary database cannot be explained by the project cost data available.

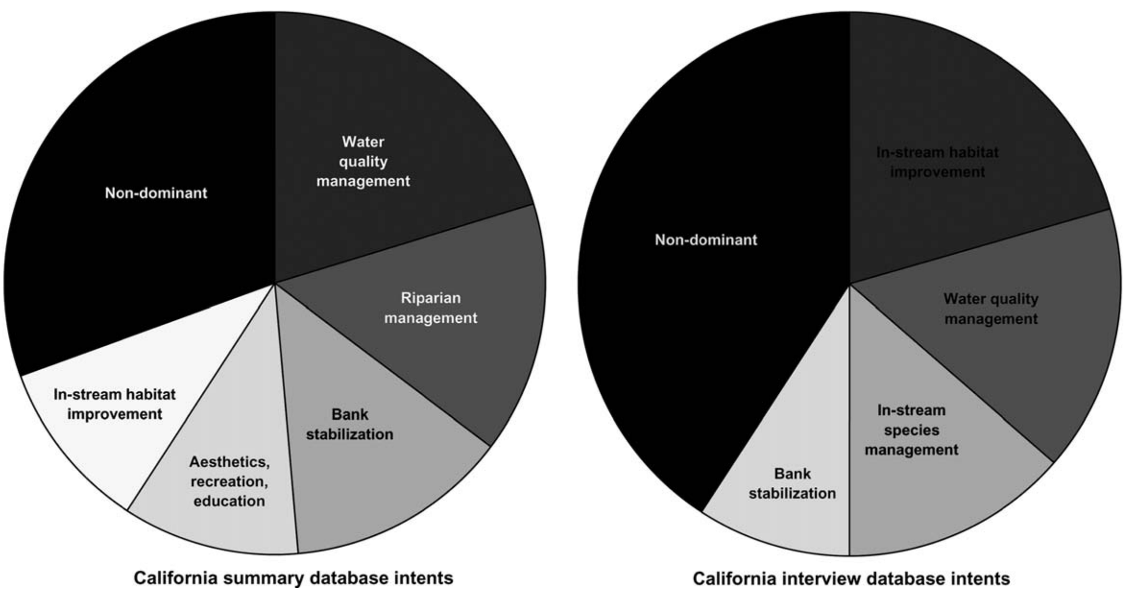

Figure 1. Relative distribution of stream and river restoration projects in California by intent (goal).

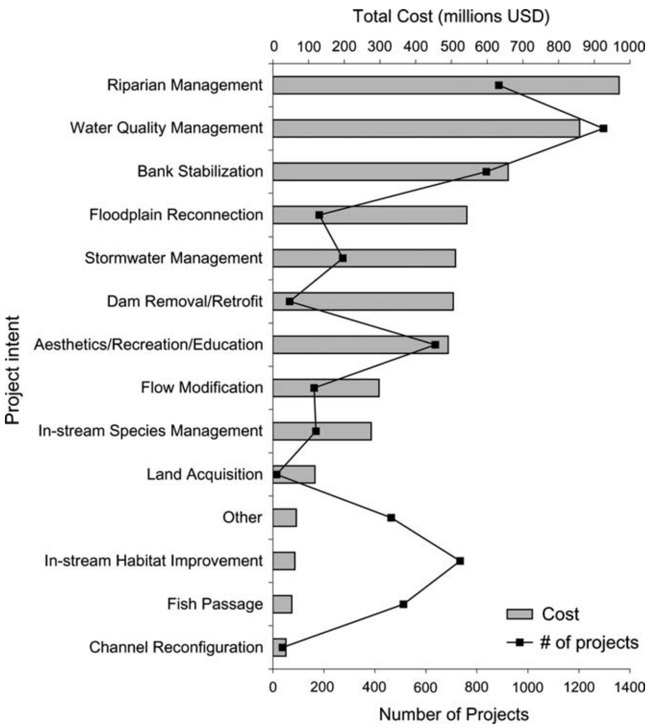

Figure 2. Total cost (millions US$) and number of stream and river restoration projects in California by project type based on written project records (summary database).

In her comprehensive inventory of restoration projects in the Russian River basin, Juliet Christian-Smith (2006) reported 787 projects, 40% more than appeared in the summary database for the same geographic area. Many of the projects not captured by the summary database were funded by local government agencies, grassroots creek/watershed groups, or private sector entities (primarily as mitigation projects) and thus were missed by the larger databases maintained by large state and federal funding agencies. We attempted to use the Lower Clear Creek watershed as a cross-reference basin too, but abandoned that attempt because of the small number of Clear Creek projects eligible to appear in the summary database.

Interview Database

Of 44 practitioners we interviewed, about a third were affiliated with nongovernmental organizations, 46% worked for local or state government agencies, and over 75% identified themselves as managers or coordinators of the projects they discussed. As was the case with other regions in the national study, the California interview database projects are not fully representative of the summary database population, reflecting only the small fraction of projects for whom we could reach the contact and for which the contact was willing to be interviewed. The high rates of abandonment were mostly in older projects. This evidently reflects staff turnover in agencies, consulting firms, and nongovernmental organizations, such that project contacts for older projects were more likely to have left the organization. As a result, the projects in the interview database are on average more recent than the projects in the summary database (median completion date of 2001 vs. 1996). Also, the projects in the interview database are typically more intensive efforts than those in the summary database: the median cost of interview database projects is $227,415, whereas the median cost of summary database projects is $50,257. Thus, the results of our interview data should not be taken as fully representative of the population of restoration projects in California despite the stratified random basis of the sample.

Most subject projects were located in central California (55%). Half occurred on private property. Thirty-six percent of the projects were implemented in agricultural areas, and 20% in urban areas; on a national level, more projects were implemented in agricultural or undeveloped watersheds (Bernhardt et al. 2007). The main incentives cited for the restoration projects were environmental degradation (52%) and funding opportunities (30%). Very few listed mitigation as the motivation for restoration, in contrast with results from the southeast node where almost half of the projects were intended as mitigation (Sudduth et al. 2007). The projects selected for interview fell under the NRRSS classifications of in-stream habitat, riparian management, water quality, and channel configuration in the summary database. However, because individual projects could list more than one intent, there was no way to determine the overarching goal of a project from a summary database record. When we asked interviewees to report their project's intent, most reported in-stream habitat improvement, water quality, and in-stream species management (Fig. 1), which is consistent with national results (Bernhardt et al. 2007).

As habitat improvement drove many of these projects, a majority of them (59%) performed some type of vegetation planting or management, particularly revegetation with native species. In contrast to the summary database, riparian management was not listed as an intent in most cases. Other common restoration activities included bank or channel reshaping and education. To the extent, it can be determined, project activities leaned toward bioengineering solutions: many projects added boulders, gravel, large woody debris, and/or root wads; and whereas two projects added riprap, three removed culverts and two removed dams. Few projects involved modifying flow, which may be attributed largely to the intent categories selected.

Costs of the projects on which we interviewed varied from $5,000 to $25,000,000, with a median cost of $227,415 (Fig. 3). The majority of projects received in-kind contributions (86%), a measure of community and landowner support for the projects, and also of the extent to which reported costs do not reflect total project costs. The value of in-kind contributions ranged from $300 to $200,000 reflecting the variety of project scales: from tens of meters to 2 km or more.

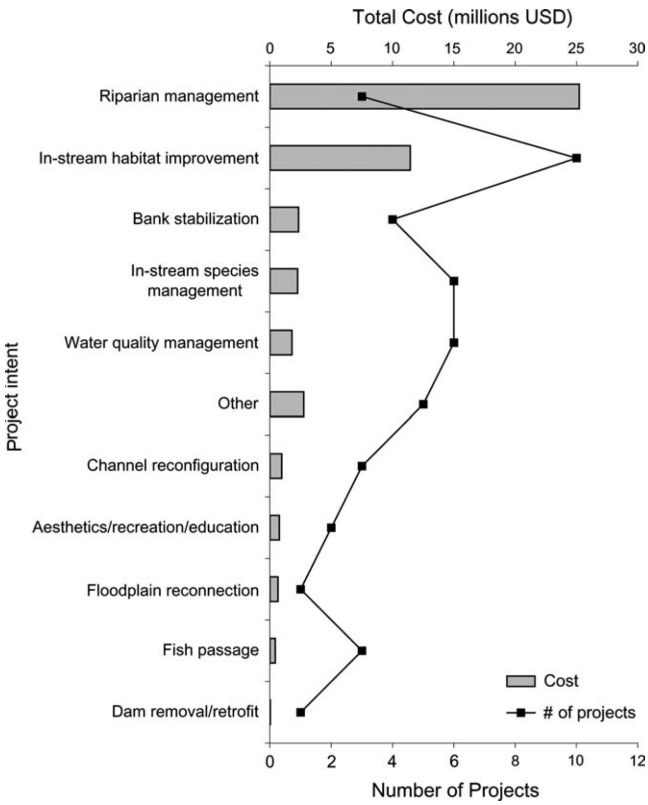

Figure 3. Total cost (millions US$) and number of stream and river restoration projects in California by project type based on interviews.

Project Design and Implementation

Over half of the interviewed projects were implemented in the context of a watershed assessment and/or a watershed management plan, but only 7% reported that a broader watershed planning perspective influenced site selection. Respondents were allowed to indicate multiple priorities for site selection, as well as the *most important* prioritization factor. Priorities cited ranged widely, with ecological concerns (50%) and available land opportunities (41%) most commonly cited. These were the two priorities most commonly cited at the national level as well, but with a substantially lower frequency (21 and 22%, respectively). Interviewees were also asked for the one or two principal factors influencing design. Here, the most commonly cited category was ecological opportunities (43%), such as a chance to improve fish passage, with ecological impacts (30%), location-specific limitations (27%), and stakeholder preferences (25%) close behind.

One-third of the interviewed projects hired a consultant to take the lead or provide input toward the restoration design, but most commonly designers were government agency staff (45%), particularly from California state agencies. This was in contrast to the national average where only 13% of projects were designed by agency staff. Interviewees reported that past experience was the most common source of knowledge influencing design (70%), in contrast to the national level where only 13% of respondents cited experience as their primary source of knowledge (Bernhardt et al. 2007). Among the California interviewees, only 9% relied primarily on preexisting frameworks like manuals, agency guidelines, or other literature, in comparison to 16% at the national level.

Consistent with national results, the vast majority (80%) of the interviewees reported that they made some effort to minimize the impact of construction efforts by changing the timing of the project to accommodate reproductive cycles of key species, relocating native plants or animals, minimizing turbidity impacts, and other related activities. At least in part, this is likely a reflection of permit-driven requirements.

Many of the interviewees drew attention to the importance of stakeholders to the restoration process, especially the case as more than half of the interviewed projects occurred on private property, 86% of projects received in-kind contributions or services from citizens and/or landowners. Half of the projects had advisory boards, composed of agency scientists, members of the public, and nongovernmental agencies. In addition, 66% of the projects in the California interview database integrated citizen input, primarily during the initiation and implementation stages (but a few during the evaluation stage).

Monitoring

Although 89% of the interviewed projects incorporated monitoring into the restoration process, no established protocol emerged among the respondents. Half of the projects conducted physical, biological, and photo monitoring, and about a third conducted chemical monitoring, roughly consistent with national results (Bernhardt et al. 2007). Funding mandate and personal commitment were the driving forces for monitoring, whereas lack of funding (48%) and lack of staff time (32%) were the main constraints. Twenty-five percent of interviewees did not report their monitoring data at all. Of those who did, the majority reported the data only to funders or permitting agencies.

Evaluation

Less than half of the interviewed projects had explicit, measurable project objectives stated in proposals or evaluation standards. Despite this, 52% of the interviewees said their projects were "completely" successful, and 36% said their projects were at least "partially" successful. Cited grounds for success included ecosystem responses, such as positive effects on fish and wildlife (59%) and on river morphology (23%). Although few projects cited improvements in-stream hydrology (7%), a number of interviewees described significant improvements in wildlife habitat and populations, including more diverse fish and avian species, and some documented sightings of threatened and endangered species in their project reaches for the first time after restoration project completion. In addition to ecological factors, interviewees cited social and organizational factors as grounds for project success, such as positive effects on community (34%) and the opportunity to build an organization's capacity for future restoration efforts (34%). Half of the interviewees reported using their monitoring data to evaluate project success. Despite the positive evaluation of their projects, most respondents reported results only in an agency or funder report and did not disseminate results to the broader scientific and practitioner community (consistent with the documentation filed with monitoring results).

Lessons Learned

Several themes emerged from answers to open-ended questions near the end of the phone survey, in which interviewees could comment on lessons learned and make suggestions for future restoration projects. There was some ambivalence expressed regarding public participation. Although most interviewees cited the critical need for stakeholder participation in the restoration process to gain support for the project and provide insight on landscape change over time, other respondents expressed dismay and regret toward uninformed stakeholders who interrupted the planning or implementation process. Several respondents suggested outreach be conducted well before project design and that all public input be formally documented to address this issue.

A consistent theme was the need to plan for unexpected circumstances and expenses beyond a typical project budget. Equipment and construction often cost more than originally anticipated. Several respondents reported that staff members spent too much of their budgets on contracting and/or administration. Funding opportunities also limited the monitoring component on many of the surveyed projects. Although most practitioners endorsed the importance of baseline and postproject monitoring, few secured the necessary funding to obtain the data, especially over the long term. Many interviewees expressed a need for standardized protocols to evaluate success, compare projects, and inform the science (though it is worth noting that developing such protocols can be challenging) (Gillilan et al. 2005; Palmer et al. 2005).

Regulatory requirements were also cited as factors slowing and thwarting restoration processes. Many of those surveyed identified the permitting process as laborious and often a barrier to efficient implementation. They suggested starting the project early to accommodate the time it would take to secure permits, especially as the rainy season can constrain construction and the growing season for plants may be limiting. A number of interviewees suggested that the California Environmental Quality Act be modified so its environmental review provisions were not obligatory for all restoration projects. Finally, many interviewees noted the importance of expecting the project and stream to evolve over time and the need for adaptive management.

Discussion

Simply developing an accurate summary database of restoration projects in California proved challenging. Many sources did not document project planning, complete final reports, or track project statistics. Most of the entries in the summary database were derived from two large databases maintained by state agencies, augmented by projects that required permitting and thus produced a paper trail. Our cross-referencing with regional experts indicated that our summary database captured most projects funded by state and federal agencies, but missed many projects from local government agencies, grassroots creek/watershed groups, and mitigation projects by private parties because these often smaller projects were not included in the large databases we mined. Obstacles to including such dispersed projects in future California database updates include the lack of a centralized repository for records and concerns about releasing information about projects occurring on private property or because of mitigation. In consolidating and validating records from multiple sources, we observed that even the agencies that tracked projects typically did not have a standard framework for reporting the results of restoration projects, sometimes missing even key details such as project title, contact, timeline, and funding sources.

We also experienced challenges in developing the interview database. Many data holders never responded to our interview requests, even after multiple attempts at communication. Of those that responded, some organizations did not maintain sufficient information on completed projects for us to make comprehensive comparisons among the 44 randomly selected projects. The incentives to build projects are evidently stronger than those to monitor and maintain records.

We conducted interviews only on projects with a knowledgeable contact person available and willing to participate in our study. Thus, our sample was biased toward bigger projects implemented by larger organizations with more stable staff. These real differences in the database populations probably explain some of the major differences between our interview and summary databases, such as the higher average costs of the projects in the interview database versus the summary database (median $227,415 vs. $50,257), and the higher percentage of projects monitored (89 vs. 22%). Another likely source of the difference in reported monitoring is that many of the sources mined for the summary database did not include a record field for monitoring. Despite these factors, the interview results make clear that far more monitoring is taking place than had been expected. The issue to be addressed, then, is not quantity, but type, duration, quality, and reporting of monitoring. In particular, an increase in funding for monitoring, the development of standard monitoring protocols, and the development of a central repository for monitoring and evaluation data could be of tremendous benefit to the restoration community. As documented elsewhere, restoration projects do not always turn out as planned, and there is potential to learn from postproject appraisals (Frissell & Nawa 1992; Downs & Kondolf 2002; Moerke & Lamberti 2003).

The restoration activities described by interviewees seem to reflect a transition from traditional engineering approaches, such as trapezoidal channels and riprap, to more environmentally oriented practices, such as stabilizing banks with vegetation and adding large woody debris or rootwads, as would be expected from projects describing themselves as "restoration," and consistent with trends toward greener river management in North America and Europe generally (Downs & Gregory 2004). Based on the interview data, however, these projects often fell short of restoring connectivity and dynamic ecological processes, and thus, the restorations follow different trajectories that the original degradation (Kondolf et al. 2006) and probably are of limited ecological value (Palmer et al. 2005).

Although half of the interviewees referred to a watershed assessment or plan, this usually did not influence site selection nor, evidently, restoration approach. However, a sound geomorphic and historical analysis at the broader catchment scale is needed to understand the underlying causes of channel change and to guide river restoration (Kondolf 1998; Downs et al. 2001). Better integration of catchment-scale understanding of process within the design phase would prioritize the location and types of projects that are most valuable to conduct and could help avoid the kind of problems caused by catchment-scale effects such as high fine sediment loadings documented by Iversen et al. (1993).

Half of the interviewees reported their projects as completely successful, after an average of only 3 years since project completion, and in most cases without having stated explicit success criteria. This reflects the fact that most project evaluation in California has been anecdotal, and current monitoring practices limit our ability to "mine" completed projects for lessons for future project design. Interviewees cited qualitative improvements in habitat supported by monitoring data—species abundance, sightings of listed fauna in the project reaches, and in a few cases, improvements in hydrologic and geomorphic function. In the Mediterranean-climate hydrology of California (Gasith & Resh 1999), it can be argued that a longer period of observation is needed to reach conclusions of project performance, so that there is more chance of observing the effects of large, infrequent events during the monitoring period. Moreover, species populations (cited frequently by interviewees as rationale for project success) are influenced by many factors besides the effects of the restoration project, implying that the direct effects of the projects on physical function (including hydrology and geomorphology) should be monitored as well (Scheimer et al. 1999). The general lack of specific success criteria probably reflects the poorly developed (or nonexistent) feedback loops between the project planning, design, and monitoring, as well as the relative immaturity of the field nationwide (Wohl et al. 2005). The California interview database did not include a single project that met the ideal standards for monitoring and evaluation developed for the national interview database in Bernhardt et al. (2007): a clearly defined goal, objective success criteria, and appropriate monitoring conducted before and after project implementation both on site and at a reference site. However, it is also important to note that many practitioners evaluated their projects on social and organizational grounds as well as ecological ones. Thus, calls for measurable success criteria as the only basis for project evaluation may miss some of the broader goals common to restoration projects and the importance of stakeholder education and involvement (Gunderson & Holling 2002).

With well over $2 billion spent on river restoration in California since 1980, the lack of objective project evaluation and dissemination of lessons learned from built projects looms as a hindrance to the evolution of the practice (Kondolf 1995). Projects should include postproject appraisals based on systematic data collection conducted over a sufficient period past project completion so that the study area has experienced high flows capable of altering the channel (Kondolf 1998; Downs & Kondolf 2002). As implementing agencies may lack the technical capacity to assess success or motivation to report failures, the role of objective postproject appraisal may fall on universities and other independent organizations with technical capabilities. In the third and final phase of NRRSS for the California node, we are conducting over 40 of such postproject appraisals in California. Results of postproject appraisals and further detail on the California summary and interview databases can be found on the NRRSS California node Web site: http://lib.berkeley.edu/WRCA/restoration/nrrss.html.

Implications for Practice

- To improve future practice, we must learn from our collective experience. This will require better documentation of our projects and their physical and ecological effects. A web-based clearinghouse for relevant project information could help.
- For many projects, evaluation of success has been largely anecdotal. Lack of clear objectives and success criteria, and the current monitoring practices, limit our ability to "mine" past projects for insights to improve future project design.
- In Mediterranean-climate coastal California, conventional notions of stability and equilibrium are usually not applicable. The highly dynamic nature of these channels must be considered when setting goals and choosing strategies more so than in regions with less variable hydrology.
- We are investing more in restoration than our figures would suggest because many projects did not report costs or include costs of agency staff time and other in-kind contributions to most projects.
- Managers reported that costs were often ultimately higher than anticipated because of construction difficulties, permit delays, and surprises. An adaptive management approach can help address unanticipated changes and keep the project on course.

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