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A SYNTHESIS OF STREAM RESTORATION EFFORTS IN FLORIDA (USA)

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ABSTRACT

Studies summarizing stream restoration projects in the US are outdated and omit the majority of restoration projects in Florida. To address this gap, we compiled stream restoration data from diverse sources to create a Florida Stream Restoration Database (FSRD, available at http://www.watershedecology.org/databases.html) containing information on project type, location, completion date, and costs. The FSRD contains 178 projects categorized by restoration type, including riparian management (23%), stream reclamation (19%), flow modification (13%), bank stabilization (12%), channel reconfiguration (11%), in-stream habitat improvements (11%), floodplain reconnection (6%), invasive species removal (4%), and dam removal (1%). Projects were spatially clustered into three geographic regions, providing insight on the diversity of initiatives, needs, and funding sources of land management agencies and private landowners that motivated restoration efforts. Projects in the Florida panhandle emphasized in-stream habitat restoration, while peninsular projects were dominated by flow modification, and projects in the west central region focused on stream reclamation to mitigate surface mining practices and water quality and habitat improvements in tidal streams. Results suggest that Florida is spending much more on stream restoration than previously documented. Between 1979 and 2015, the mean and median stream restoration project costs in Florida were $15.4 million and $180 000, respectively, indicating a strongly skewed distribution because of the large Kissimmee River restoration project in central Florida. This work highlights the need for, and utility of, statewide and national restoration databases to improve restoration tracking. This need will become increasingly critical as more stringent water quality and habitat mitigation rules are implemented across the country. Copyright © 2016 John Wiley & Sons, Ltd.

KEY WORDS: river restoration; GIS; Clean Water Act; impairment; database

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INTRODUCTION

Motivations for river and stream restoration are diverse. Globally, restoration efforts have been driven by declines in fish stocks, increased flooding, habitat degradation, and water quality declines (Wheaton *et al*., 2006; Roni *et al.,* 2008; Dufour and Piégay, 2009; Gilvear *et al.,* 2012). In the US, stream restoration efforts have been recorded anecdotally as early as the late 1800s (Roni and Beechie, 2012), and over $1 Billion USD annually is currently spent on restoration to improve or repair degraded US streams and rivers (Bernhardt *et al.,* 2005). Despite this significant investment, there have been limited national-scale data collection efforts to catalogue projects or evaluate restoration effectiveness (US National Research Council, 1992; Bernhardt *et al.,* 2005; Gilvear *et al.,* 2012). Existing reviews of the practice are regional (Kondolf, 1998; Carpenter *et al.,* 2004; King *et al.,* 2009; Rios-Touma *et al.,* 2014), focused on a specific restoration strategy (Harrison *et al.,* 2004; Thompson, 2005) or stream type (Carpenter *et al.,* 2004), or are meta-analyses of other studies (Craig *et al.,* 2008; Roni *et al.,* 2008).

The collection, synthesis, and evaluation of restoration projects continue to be a challenge (Jenkinson *et al.,* 2006) for several reasons: (i) data on stream restoration are considered fragmented or incomplete because of varying reporting requirements by agencies responsible for restoration (Kondolf and Micheli, 1995; Bernhardt *et al.,* 2005; Beechie *et al.,* 2009); (ii) data that do exist vary in detail specific to the needs of the data sources (i.e. permitting agency, funding source, or news articles); and (iii) information about restoration projects is often recollected anecdotally and therefore may be lost in personnel changes. It has been ten years since the last national survey of river restoration in the United States (Bernhardt *et al.,* 2005) was conducted. Since then, a number of new environmental regulations and new interpretations of existing rules have been implemented (e.g. federal numeric nutrient criteria and state minimum environmental flow regulations), stream restoration techniques have advanced, and the total number of completed projects has increased greatly.

Despite Florida's efforts in environmental conservation, land acquisitions, and water quality improvements, national

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and regional restoration data (Carpenter *et al.,* 2004; Bernhardt *et al.,* 2005; Sudduth *et al.,* 2007) fail to sufficiently describe stream restoration efforts in the state. Studies generally either only discuss landmark projects, such as restoration of the Apalachicola River, Kissimmee River, and the Everglades, or exclude Florida from the discussion altogether. Indeed, Bernhardt *et al.* (2005) cite only four projects in Florida, and the state does not appear in their comparisons of regional differences. This study aims to fill that knowledge gap by cataloging and synthesizing restoration projects in Florida into a Florida Stream Restoration Database (FSRD). Our research goals are to answer four central questions about river and stream restoration in Florida: (i) Where are the major sources of stream restoration data? (ii) What types of stream restoration are occurring? (iii) Are there spatial and/or temporal trends in the practice of restoration? (iv) How much money is spent on restoration, and how does this amount compare to national restoration expenditures?

METHODS

Data collection

Restoration project data were collected from various sources, including organizations that fund restoration projects, governmental environmental protection agencies—many of which were used by Bernhardt *et al.* (2005) in their restoration synthesis—and various web-based data sources. This effort identified several key databases containing information on restoration projects in the state including: restoration grants databases, Environmental Resource Permit (ERP) databases from the Florida Department of Environmental Protection (FDEP), and the state's five Water Management Districts (WMD), and dredge and fill permits from the US Army Corps of Engineers (USACE). These databases contain thousands of restoration projects, including storm water improvements, implementation of best management practices (BMPs), wetland restoration, and coastal ecosystem restoration. Keyword searches were used to identify relevant stream restoration projects. Because of limited documentation in a number of these databases, 'snowball sampling' (Biernacki and Waldorf, 1981) was also used to identify stream restoration professionals in the state and collect information about the projects they have implemented, starting with a list of known contacts in the field. E-mail requests for restoration data were sent to the restoration professionals on this list, along with a request for additional contacts, who were subsequently sent the same request (hence the 'snowball' effect). Primary contacts included scientists at the US Geological Survey, members of the Florida Section of American Water Resources Association (AWRA), and faculty from the University of Florida. Data were also requested through the monthly newsletter of the Florida section of the AWRA.

Projects were identified as restoration if they met the criteria defined by the 2008 Federal Mitigation Rule: 'Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource' (National Research Council (US), 1992; US Army Corps of Engineers and US Environmental Protection Agency, 2008). The geomorphic definition of a 'stream corridor' was used to differentiate stream restoration from upland restoration (Federal Interagency Stream Restoration Working Group, 1998). Under these criteria, projects that entailed in-stream and riparian restoration activities were selected for the database. Duplicate projects and projects such as agricultural BMPs, storm water enhancements, or upland vegetation restoration projects were excluded from FSRD if they did not meet the defined restoration criteria. Thus, the emphasis was on reach-scale and in-stream restoration efforts with direct impact on stream form and/or function. Several basin-scale restoration projects were also included; these were large-scale projects that reconnected floodplains or backfilled canals or enhanced in-stream flows.

Projects that met the selection criteria were classified into categories representing restoration 'type.' Restoration types were modelled from previous studies in the National River Restoration Science Synthesis (Bernhardt *et al.,* 2005; Sudduth *et al.,* 2007) and were categorized by the primary type of restoration activity performed (as opposed to using multiple categories) to avoid double counting (Table I). Occasionally, projects fit into a number of project types. For example, a bank stabilization project activity may have an additional benefit of in-stream habitat improvement. In these cases, the category that was listed as the primary restoration activity was chosen. Two categories not included in previous efforts (invasive species removal and stream reclamation) were included in the FSRD. These new categories address restoration activities in Florida that may have been less prevalent in other regions of the US. Mine reclamation in Florida often involves *creating* streams on previously surface-mined phosphate lands in central Florida. Moreover, several projects cited invasive species removal as a primary restoration activity. Several categories such as water quality management, land acquisition, and stormwater management used in the NRRSS were not included in the FSRD. These projects were considered passive rather than active restoration, which was the focus of this study.

Data analysis

Project descriptors and geographic and physical attributes were assigned to each project using a GIS database. Project

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Table I. Comparison of restoration categories identified in prior studies (Bernhardt *et al.,* 2005; Sudduth *et al.,* 2007) and this study

Project type	Prior studies	This study	Description
Water quality management	X		Practices that protect existing water quality or change the chemical composition and/or suspended particulate load
Riparian management	X	X	Revegetation of riparian zone/removal of exotic species
Channel reconfiguration	X	X	Alteration of channel plan form or longitudinal profile and converting culverts to open channels.
Land acquisition	X		Obtain lease/title/easements for the explicit purpose of preservation, removal of impacting agents, or restoration
Bank stabilization	X	X	Reduce or eliminate erosion
In-stream habitat improvement	X	X	Altering the structural complexity to increase habitat availability and diversity for target organisms.
Fish passage	X		Removal of barriers to migration of fishes
Storm water management	X		Construction and management of structures in urban areas to modify the release of storm runoff.
Aesthetics/restoration/ education	X		Activities that increase community value: use, appearance, access, safety, knowledge
In-stream species management	X		Directly alter aquatic native species distribution and abundance, e.g. stocking
Flow modification	X	X	Practices that alter the timing and deliver of water quantity and canal backfilling
Floodplain reconnection	X	X	Practices that increased the flood frequency of floodplain areas or promote flux of organisms and materials between riverine and floodplain areas
Dam removal/retrofit	X	X	Removal of dams and weirs or retrofits to reduce negative ecological impacts.
Stream reclamation		X	Recreation of streams on previously surface mined phosphate lands.
Invasive removal		X	Removal of invasive species

descriptors consist of a project description, size, cost, start year, end year, data source, and funding programme. It is often difficult to compare project size across different project types because restoration may be measured via area (e.g. floodplain reconnection) or length (e.g. channel reconfiguration). Therefore, projects were assigned a scale (i.e. in-stream, reach, or basin) that best represented the project scale (Figure 1) based on available data and project descriptions. Each attribute, excluding region, was obtained spatially from the appropriate GIS shape files.

Spatial distribution of projects was described based on three regional groups: panhandle, peninsular, and central FL (Figure 2). These regions were delineated based on physiographic and geographical characteristics and also reflected spatial clustering of specific restoration projects and project types. We note that a lack of restoration projects in south Florida represents a lack of rivers and streams in this area dominated by large lotic wetland systems (the Everglades, Big Cypress National Preserve, etc.), not a lack of restoration activity. Stream reclamation projects were specific to

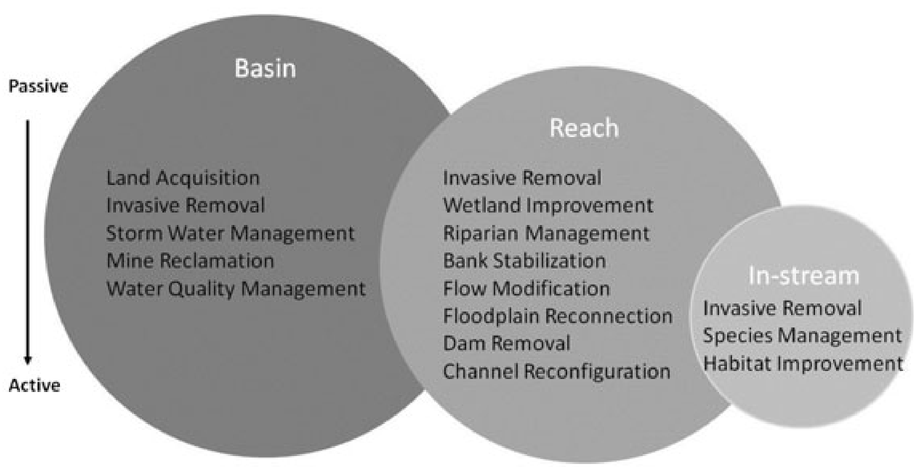

Figure 1. Restoration project types organized by project scale

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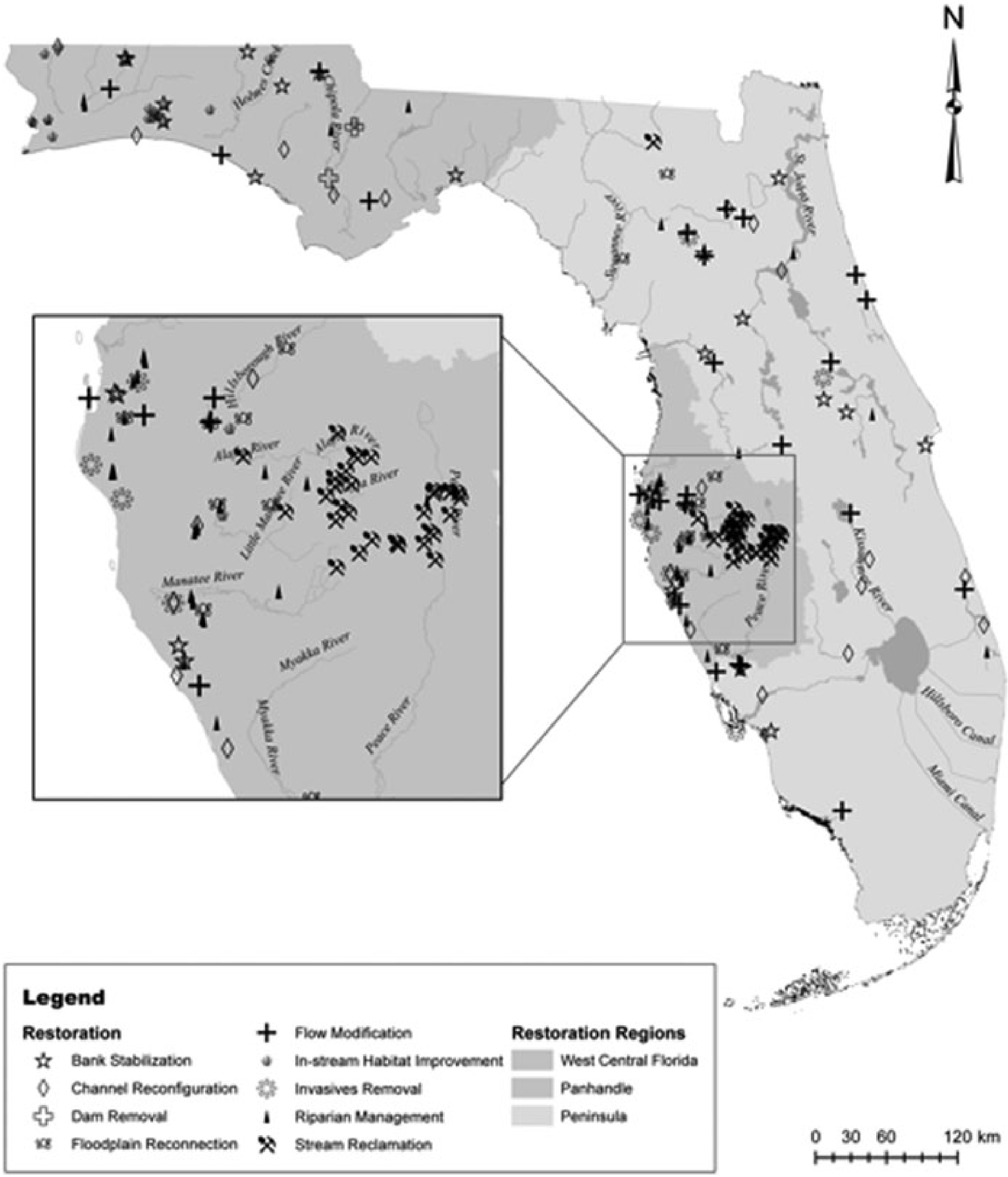

Figure 2. Spatial distribution of 178 restoration projects and project types in the Florida Stream Restoration Database (FSRD, available at http://www.watershedecology.org/databases.html)

the central Florida mining region and were excluded from further project type comparisons between regional groups. Projects were also evaluated based on additional spatial attributes, including proximity to the coast, land use/ownership, and location within urban boundaries. The proportion of projects within the saltwater interface was estimated based on the location of tidal creeks (Florida Department of Environmental Protection, 2013). Projects within the boundaries of a city were labelled as urban, while the remaining projects were labelled as rural. Similarly, projects completed on public lands (local, state and national parks, state and national forests, water management district lands, and other acquired conservation lands) were identified and labelled as public.

Project costs were described based on the number and percentage of available data and standard summary statistics

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for each project type. If available, a project completion date was determined for each project; for several projects, completion dates were estimated based on ERP expiration dates. A linear trend was fit to project completion data to describe the overall trend in the number of projects completed per year.

RESULTS

Database compilation

A total of 178 stream restoration projects with sufficient data were identified for inclusion in FSRD (Figure 2; data available at http://www.watershedecology.org/databases.html). Data sources were distributed among county, state, federal, and non-profit agency websites, as well as references from restoration practitioners and ERP applications (Table II). Several of the data sources were complete, including several in-depth restoration databases (e.g. the Tampa Bay and Sarasota Bay Estuary Programs and the Florida Ecological Restoration Inventory [FERI]). Other sources house data relevant only to specific programme objectives. For example, permitting databases include information on project size, location, and permitting process tracking but do not indicate project costs, funding sources, or success. In some cases, projects were identified in multiple data sources; although a project was only entered into the FSRD once, relevant data from multiple sources (when available) were used to create a complete attribute set. Importantly, projects obtained via snowball sampling revealed 23 projects (12%) that were not readily identifiable from permit or grant databases (Table II).

Project types

Projects were categorized into one of nine groups by restoration type (Table I) and were well distributed between project types (Figure 3). Riparian management and stream creation on mined lands (i.e. 'stream reclamation') were the most prevalent restoration types, while there were only two dam removal projects (i.e. <1% of all projects), both of which were located in the panhandle. Table III summarizes the variety of restoration activities utilized for each restoration type noted in project descriptions. Channel excavation, invasive removal, and vegetation planting

Table II. Data sources that contributed to the stream restoration database in this study

Data source	Source type	URL	# projects
Gulf Base Website	Funding Database	http://www.gulfbase.org/project/	1
National Fish and Wildlife Foundation	Funding Database	http://www.nfwf.org/whatwedo/grants/search/Pages/Grant-Search.aspx	1
Pinellas County	Project Database	http://www.pinellascounty.org/resident/nature_environment.htm	1
Nature Conservancy	Project Management Database	http://www.tnclands.tnc.org	1
Suwannee River Water Management District	Practitioner Source	N/A	2
FDOT Mitigation Plan	Report	N/A	2
FDEP 319 Grant Database	Funding Database	http://www.dep.state.fl.us/water/nonpoint/319h.htm	3
News Sources	Literature	N/A	4
Army Corps ORM Database	Permit Database	http://www.dep.state.fl.us/Water/wetlands/erp/index.htm	5
5 Star Wetland Restoration Grant	Funding Database	http://water.epa.gov/grants_funding/wetlands/restore/states.cfm#fl	8
South West Florida Water Management District	Permit Database	http://flwaterpermits.com	9
Sarasota Bay Estuary Program Website	Project Management Database	http://sarasotabay.org/habitat-restoration/habitat-restoration-map/	10
Water Management District Permit Portal	Permit Database	http://flwaterpermits.com	11
FDEP ERP Database	Permit Database	http://flwaterpermits.com	12
Snowball Sampling	Practitioner Sources[1]	N/A	23
Tampa Bay Estuary Program Database	Project Management Database	https://www.tbeptech.org/data	25
Florida Ecological Restoration Inventory (FERI)	Project Database	http://www.dep.state.fl.us/water/wetlands/feri/	29
FDEP Mining Report	Report	N/A	31
		Total:	178

[1]Practitioner sources are recognized in the acknowledgements.

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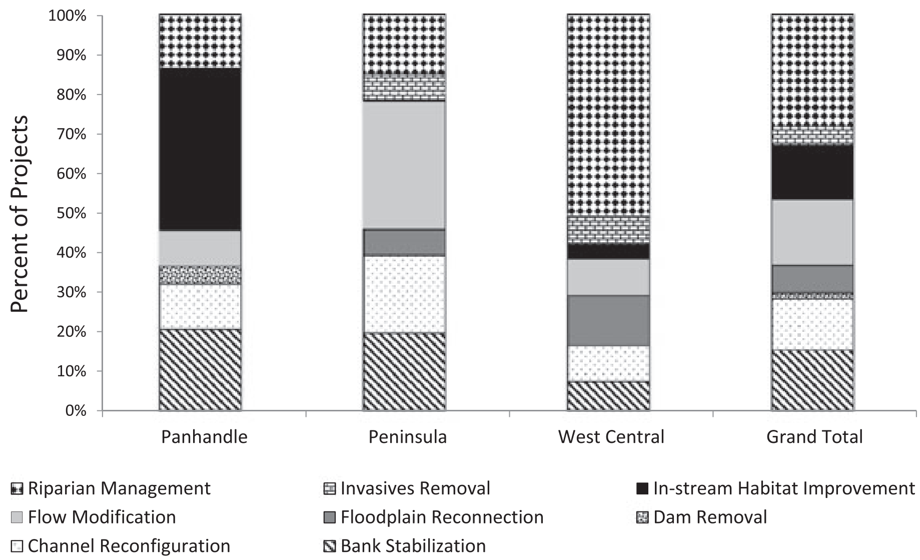

Figure 3. Regional distribution of restoration project types. Stream reclamation projects have been removed from this regional comparison, as this project type dominates the West Central region but is not found elsewhere

Table III. Restoration activities commonly associated with each project type

Restoration project type	Commonly associated activities
Bank stabilization	Gabion mat/basket, natural vegetation community restoration, stairs to protect bank, vegetation, grading
Channel reconfiguration	Diverting flows to natural channel, diversion structure, canals to natural channels, riparian wetland grading, regrading, channel excavation
Dam removal	Dam removal
Flow modification	Restoration of ditches, culverts, channel excavation/dredging, construct weir, berm removal, canal restoration
In-stream habitat improvement	Log, root wad, and boulder vane installation, stabilizing stream bank, remove beaver dam, dredging
Invasive removal	Removal of wild taro and Brazilian pepper
Stream reclamation	Stream creation using natural weathering, mechanical construction, hydraulic construction
Riparian management	Replanting vegetation habitat improvement, invasive removal, road closing, vegetation planting, reconnect wetlands
Floodplain reconnection	Grading banks, vegetation planting

were the most common activities and were utilized for multiple project types (e.g. channel excavation was employed for both flow modification and in-stream habitat improvement projects). Projects in the FSRD also varied in scale; 87% were reach-scale projects, 12% were in-stream, and 7% were implemented at the basin scale. Basin scale projects include several large projects comprising multiple phases and/or many sub-projects dispersed throughout a watershed, but with a single unifying goal. For example, the Tampa Bay Tidal Tributaries Project consisted of several sub-projects to reduce sediment loads to Tampa Bay and the Kissimmee River Restoration Project, which consisted of 32 sub-projects to restore natural flows into Kissimmee River.

Spatial distribution

Stream restoration projects in Florida were distributed across much of the state (Figure 2). A total of 47 projects were identified in the peninsula and 44 projects were identified in the panhandle, both comprising a variety of project types (Figure 3). The central region had the largest number of projects (87), which included 32 stream reclamation projects and a variety of projects focused on improving water quality in Tampa Bay. If excluding stream reclamation projects, each region contained approximately 30% of the projects identified in the FSRD, however, project types were not evenly distributed spatially (Figure 3). Projects in the panhandle and peninsula regions were dominated by in-stream

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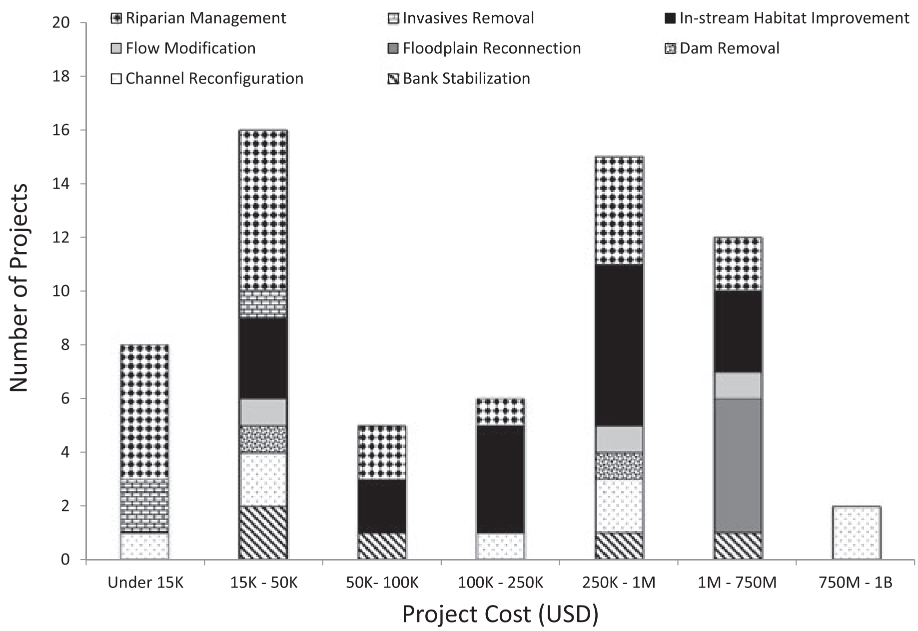

Figure 4. Number of projects distributed by type and project costs (corrected for inflation by a Consumer Price Index [CPI] cost index of 0.037 per year)

habitat and flow modification projects, respectively. As noted above, the panhandle region also contained the only dam removal projects identified in the FSRD, as may be expected based on the greater relief (and therefore greater incidence of dam construction) in this region. In the west central region, projects were primarily riparian management.

Regarding other spatial attributes, a total of 12% of projects were performed in tidally influenced streams, while another 28% of projects were located within 2 km of the coast (i.e. a total of 40% of all projects were located <2 km from the coast). These projects were dominant in the Tampa Bay area, with ~30% categorized as riparian management. Throughout the state, projects were located predominantly in rural areas, with only 18.5% of projects located within city boundaries (i.e. urban). In addition, many stream restoration projects (~60%) were located on public lands including state parks, water management district lands, and local parks. An additional 19% of projects were located on lands owned by phosphate mine companies, while the remaining 21% were distributed between private land owners or unknown ownership.

Project costs

Table IV summarizes stream restoration reported costs by project types in the FSRD. Project types with the most cost data available included in-stream habitat, riparian management, floodplain reconnection, and channel reconfiguration (Table IV). Project cost data were found in funding programme databases, project management databases, or

Table IV. Summary of project costs by project type. Costs are corrected for inflation by a Consumer Price Index (CPI) cost index of 0.037 per year

Project type	# projects	Projects w/ $ data	Sum	Average	Min	Max
Bank stabilization	22	5	$1 948 590	$389 718	$15 000	$1 212 242
Channel reconfiguration	19	8	$922 307 476	$115 288 434	$7209	$910 643 150
Dam removal	2	2	$585 469	$292 735	$83 093	$502 376
Floodplain reconnection	10	5	$7 337 186	$1 834 296	$1 127 533	$2 585 845
Flow modification	24	3	$1 478 060	$739 030	$417 648	$1 060 412
In-stream habitat improvement	20	18	$16 453 122	$914 062	$31 121	$8 544 076
Invasive removal	7	3	$43 311	$14 437	$5 513	$29 741
Riparian management	41	20	$10 326 568	$516 328	$12 891	$4 855 747
Stream reclamation	33	0	N/A	N/A	N/A	N/A
Total	178	64	$960 479 781	$15 491 609	$5 513	$910 643 150

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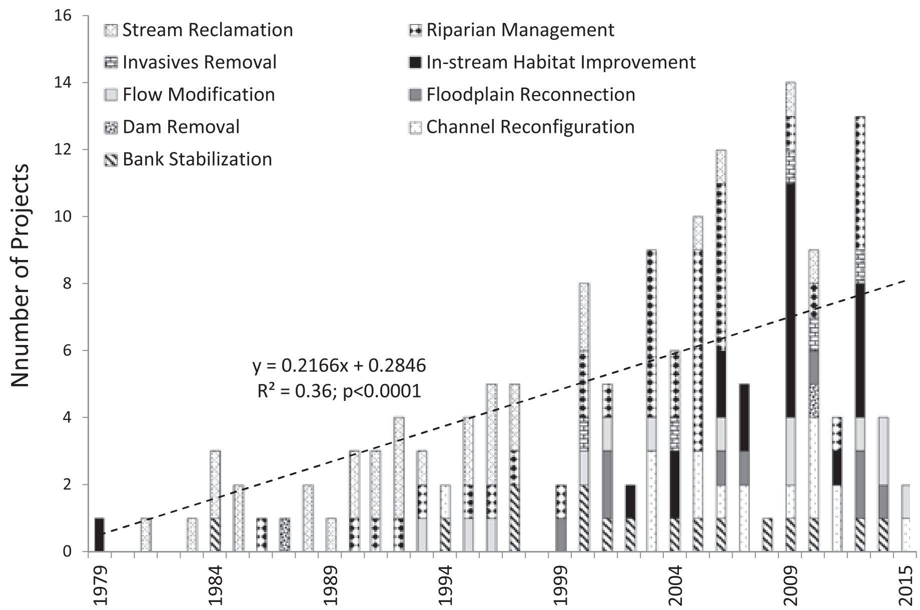

Figure 5. Timeline of restoration completion dates by project type for projects where data were available ($n = 147$ of 178 projects in the FSRD)

practitioner data sources. In some cases, costs reported by funding agencies (i.e. through grants) may not reflect total project costs, particularly for projects funded by multiple agencies or granting programmes. Moreover, grants often only fund a portion of the project, with other funds provided by local matches (cash and/or in-kind services). Additionally, there are many ‘soft’ costs associated with various phases of a restoration project that are difficult to quantify including planning, design, implementation, monitoring, and maintenance, which may be funded through existing staff salaries. The costs of reclamation of streams on mined lands were not available; this information is proprietary and is usually incorporated into the cost of regular mining activities. Similarly, extracting restoration project cost was difficult for some projects on state managed lands because restoration projects may be lumped together with routine park management activities.

Despite these challenges, we identified data describing project costs for 36% of the 178 projects in the FSRD. Averaged across the 36 years covered by the FSRD, ~$28 million has been spent annually on stream restoration in Florida (though expenditures are variable based on specific project start and end dates). Average inflation-adjusted project cost was approximately $15.4 million; median project cost was $180 000, however, reflecting a strongly skewed cost distribution driven by the channel reconfiguration of the Kissimmee River (a $980 million project). For reference, the Kissimmee project had costs 130 times greater than those for the next most expensive project, channel reconfiguration in Big Escambia Creek. Based on available data, channel reconfiguration represented the highest average cost per project type (Table IV), while the least expensive projects (all under $15 K) included riparian management, invasive species removal, and a single inexpensive channel reconfiguration (Figure 4).

Temporal trends

Projects in the FSRD were completed between 1979 and 2015 (Figure 5), and 83% of projects reported completion dates. Since 1983, at least one project has been completed each year (with the exception of 2008), and there is an overall increasing trend in the number of projects completed annually ($p < 0.0001$). The results suggest two key time periods in Florida’s stream restoration: an early era from 1979 to 1999 and a more recent era from 2000 to 2015. Differences in the number of projects completed and the variety of project types were observed between these two time periods. First, the *quantity* of projects increased substantially from an average of 1.7 (from 1979 to 1999) to four projects per year (after 2000). Second, the *variety* of project types also increased over time. Early projects were dominated by stream reclamation projects, followed by invasive removal. In later years, flow modification, riparian management, and bank stabilization projects became dominant. On average, there were two project *types* being completed annually before 2000, while in the past decade, there were an average of four project types completed per year.

DISCUSSION

A national synthesis of river restoration by Bernhardt *et al.* (2005) included a wide range of direct and indirect activities

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considered to be restoration. Since then, there have been a number of regional or specialized sources of data that catalogue stream restoration; however, the practice has not been previously evaluated in the state of Florida. While Florida is perceived as a leader in protecting natural resources through land acquisition for conservation, water quality improvements, and wetland restoration (River Federation, 1996; Farr and Brock, 2006; Wang, 2011), this failure to systematically catalogue stream restoration projects as a body has had several management and practical implications. First, it is difficult to assess the current state of stream restoration in the state without a central repository for stream restoration data. Second, without this this structure in place, it is difficult to evaluate the success of restoration activities in order to improve the practice. Third, we are unable to efficiently transfer restoration knowledge (i.e. across regions or between agencies and other stakeholders), because data are compartmentalized. In this work, we have started the process of addressing these issues through the development of the Florida Stream Restoration Database (FSRD; available at http://www.watershedecology.org/databases.html) to synthesize stream restoration efforts in Florida. Through this effort, we have identified the major sources of stream restoration data in the state and have compiled data on 178 in-stream, reach-scale, and basin-scale stream restoration projects.

Restoration project data were derived from a variety of sources including permit application data; federal, state, and regional governmental and NGO grants databases; and individual restoration practitioners. Because these data sources were developed for specific (and different) purposes, the quantity and quality of information they provided varied from basic (i.e. name, location, and description) to detailed (i.e. name, location, cost, objectives, size, etc.). The compilation of varied data source is inherently limited by differences in data quality, highlighting the need for a centralized and standardized platform for the reporting and archiving of stream restoration data (discussed further below). Despite these limitations, this effort succeeded in identifying major spatial and temporal trends in the implementation of stream restoration in Florida.

When excluding stream reclamation projects (which are specific to the west central Florida mining region), the *number* of projects completed was distributed relatively evenly across the state (Figure 2); however, the most common project types in each region varied widely (Figure 3). While reach-scale riparian management and stream reclamation were the most common restoration types, regional clustering of project types was a reflection of physiogeography (i.e. dam removal was limited to the panhandle) and specific regional priorities and funding sources (i.e. tidal stream restoration for water quality and habitat improvement and phosphate mine reclamation to mitigate strip mining practices in the west central peninsula). Additional examples of region-specific projects include habitat restoration projects in the northern Panhandle to protect the endangered Okaloosa Darter (funded by the US Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission) and a number of stream and riparian wetland restoration projects on state forest lands (funded by the Florida Forest Service).

Previous national stream restoration studies did not include stream reclamation on mined lands, yet this type of restoration is an important category in west central costal Florida. In west central Florida, stream reclamation projects specific to the phosphate mining industry represented a substantial proportion (19%) of restoration activities across the state. Stream reclamation on mined lands benefit from years of research and previous pilot projects that are now in later stages of maturity, and a number of restoration ‘best practices’ have been developed (Hawkins and Ruesch, 1988; Lewelling and Wylie, 1993; Blanton *et al.,* 2010). Recent formats of stream reclamation utilize integrated surface water and groundwater modelling, stringent monitoring requirements, improved stream characterization, and innovative stream channel creation techniques. An example of that innovation is using hydrological and mechanical stream creation techniques. The mechanical stream creation techniques have the potential of reducing the time for full-stream maturity from 15 to 20 years to 7 to 12 years (John Kiefer, Principal Engineer, AMEC, personal communication, 2 Feb 2013). These techniques are a key example of the convergence of restoration practice and science needed for successful ecological function (Wohl *et al.,* 2005; Palmer and Bernhardt, 2006; Beechie *et al.,* 2009; Bennett *et al.,* 2011).

While is difficult to quantify the exact sum spent on stream restoration in Florida, this analysis synthesized all currently available data. Total expenditures over the 36 years covered in the FSRD were approximately $1B, equal to the estimated annual spending on restoration nationally between 1994 and 2005 (Bernhardt *et al.,* 2005). Two large projects skewed the restoration cost distribution; mean project cost was $15.4 million while median cost was $180 000. The generally bimodal distribution of project costs (Figure 4) reflects an abundance of low cost projects (funded primarily through granting agencies and implemented at the small scale by land management agencies) and high cost projects (multi-agency projects with or without external grant funding implemented at much larger scales), with fewer moderate-cost projects.

As priorities in restoration efforts shift over time, funding for certain types of restoration projects fluctuates. However, we found a general trend indicating an increase in both the number and types of projects completed over time (Figure 5). While it is possible that this trend reflects the availability of older records and/or experts’ fading memories from earlier projects, it is concordant with a general increase

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in the awareness and funding availability for ecosystem restoration nationally (BenDor *et al.,* 2015) and internationally (Brancalion *et al.,* 2014). The temporal trend observed in this study is likely a function of both environmental priorities and available funding, with the greatest number of projects likely to occur when priorities and funding sources are well aligned; when regional priorities are out of sync with funding opportunities, new restoration projects are difficult to initiate. To overcome a general paucity of funding, other strategies for funding restoration are increasingly being sought, such as market-based restoration or restoration for mitigation purposes (Lave *et al.,* 2010). These activities have the potential to change the way restoration is conducted and distributed across a region. For instance, an analysis of mitigation banking in North Carolina suggested inconsistent permitting practices and mitigation occurring at great distances from the impact even in other watersheds (BenDor *et al.,* 2009).

There were several challenges in identifying projects to include in the FSRD, highlighting the need for an improved restoration project cataloging mechanism. In most instances, projects were embedded in larger databases (i.e. ERP databases, EPA 319 database, or FERI database) with limited or no identifying markers. In cases where descriptive fields did exist, they were often mislabelled. For example, a field to indicate that a project is indeed 'restoration' is lacking when applying for many permits; therefore, users of those databases are unable to easily identify restoration projects. Second, projects are sometimes embedded in permits for larger projects such as suburban development subdivisions, mitigation banks, conservation projects, or routine agency land resources management efforts, and restoration efforts within these projects are easily missed. Stream restoration projects may also be part of a multi-year effort where projects are conceptualized, designed, and permitted before financing is secured. In some cases, multiple permits are filed describing the same project with differing information. These projects are then implemented in stages, completed in segments over a number of years, or delayed until funding is secured. Finally, the methodology presented here does not capture the thousands of volunteer hours that come from environmental organizations each year to remove invasive species to improve in-stream habitat, remove trash from stream channels, or re-plant riparian vegetation to improve bank stabilization. These efforts are difficult to quantify because they are localized efforts and are typically only catalogued by individual organizations. Quantifying projects in each of these categories would certainly increase the final project count and enhance the understanding of stream restoration efforts in the state.

Restoration tracking becomes particularly important as more stringent water quality and mitigation rules come into effect. In Florida, these include new Numeric Nutrient Criteria [NNC] recently negotiated between the US Environmental Protection Agency and the FDEP (62-302.531, Florida Administrative Code [FAC]) as well as statewide Uniform Mitigation Assessment Methods (UMAM; 62-345, FAC) and Minimum Flow and Level (MFL) regulations (Section 373.042[1], Florida Statues). Similar efforts to strengthen regulations protecting water quantity and quality are being implemented or proposed nationwide, from Georgia (GAEPD, 2013) to Alaska (Title 18, Chapter 70, Alaska Administrative Code). River and stream restoration will likely play a large role in this effort to better protect water resources, emphasizing the importance of restoration project-tracking efforts like the FRSD.

As a solution to the incomplete and unstandardized nature of current data sources, a restoration-tracking database is a useful tool for planning and management purposes (Palmer and Allan, 2006). Here we present a standardized restoration database for Florida with a number of tangible benefits to the practice: (i) it improves institutional memory regarding restoration activities because anecdotal data are so easily lost; (ii) it improves the ability to assess the success of restoration on a variety of scales within the state; (iii) it raises awareness of the various types of restoration that are occurring across the state; and (iv) it identifies restoration practitioners and their specific areas of expertise. By synthesizing stream restoration projects in Florida, the FSRD (available at http://www.watershedecology.org/databases.html) will help to maintain the institutional memory, guide future efforts, and help others evaluate restoration outcomes in the future.

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