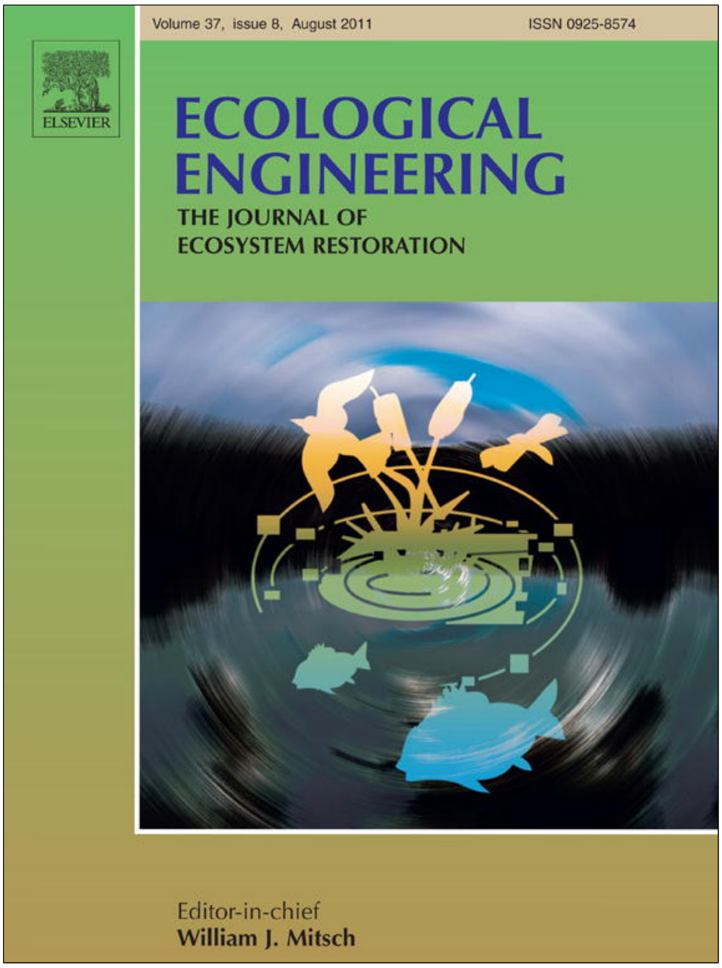
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Short communication

Soft shoreline engineering survey of ecological effectiveness

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ABSTRACT

Historically, many urban waterfront shorelines were stabilized using hard shoreline engineering to protect developments from flooding and erosion, or to accommodate commercial navigation or industry. Today, there is growing interest in developing shorelines using ecological principles and practices that enhance habitat and improve aesthetics, while at the same time reducing erosion, providing stability, and ensuring shoreline safety (i.e., soft shoreline engineering). In 2008–2009, a survey of 38 soft shoreline engineering projects in the Detroit River-western Lake Erie watershed was conducted. In total, $17.3 million (combined U.S. and Canadian currency) was spent on these projects. Of the 38 projects implemented, six (16%) had some quantitative assessment of ecological effectiveness, while the remaining 32 lacked monitoring or only had qualitative assessment through visual inspection. Key lessons learned include: involve habitat experts at the initial stages of waterfront planning; establish broad-based goals with quantitative targets to measure project success; ensure multidisciplinary project support; start with demonstration projects and attract partners; treat habitat modification projects as experiments that promote learning; involve citizen scientists, volunteers, and universities in monitoring, and obtain post-project monitoring commitments up front in project planning; measure benefits and communicate successes; and promote education and outreach, including public events that showcase results and communicate benefits.

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1. Introduction

Habitat loss and degradation is a major issue throughout much of the Great Lakes region, especially in urban and industrial areas. For example, Manny (2003) has documented a 97% loss of coastal wetland habitats along the Detroit River due to human shoreline development.

Historically, it was common practice to utilize hard shoreline engineering to further commercial development. Hard shoreline engineering is generally defined as the use of concrete breakwalls or steel sheet piling to: stabilize shorelines for erosion and flooding protection; achieve greater human safety; and/or accommodate commercial navigation or industry (Caulk et al., 2000). Although hard shoreline engineering can achieve commercial, navigational, and industrial benefits, it results in negative ecological impacts because it provides no habitat and restricts access to adjacent habitats. Such anthropogenic hardening of shorelines not only destroys natural features and biological communities, but also alters the transport of sediment, disrupting the balance of accretion and erosion of materials carried along the shoreline by wave action and long-shore currents. This disruption of sediment transport processes can intensify the effects of erosion, causing ecological and economic impacts (Schneider et al., 2009).

Along the Detroit River, 49.9 of 51.5 km of the U.S. mainland have been hardened with concrete or steel (Manny, 2003). Schneider et al. (2009) have reported that 47.2% and 20.4% of the entire U.S. and Canadian Detroit River and Lake Erie shorelines, respectively, are "highly protected" using hardening techniques. Changes in the extent of hardening or armoring along western Lake Erie's shoreline have been documented by Ohio Department of Natural Resources since the 1870s (Fuller and Gerke, 2005; Livchak and Mackey, 2007). In the 1930s, less than 5% of Ottawa and Lucas County lakeshore was hardened or armored. As of the 1990s, 78% of the Ottawa County lakeshore and 98% of the Lucas County lakeshore were hardened or armored, representing substantial loss of habitat.

Today, there is growing interest in designing shorelines for multiple purposes so that additional benefits can be accrued (Borsje et al., 2011). Soft shoreline engineering (SSE) is the use of ecological principles and practices to reduce erosion and achieve stabilization and safety of shorelines, while enhancing riparian habitat, improving aesthetics and even saving money (Caulk et al., 2000; Hartig et al., 2001; Jones and Hanna, 2004). SSE is achieved by using

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vegetation and other materials to improve the land-water interface by improving ecological features without compromising the engineered integrity of the shoreline. In 1999, a U.S.–Canadian SSE conference developed a best management practices manual (Caulk et al., 2000) to encourage use of SSE techniques. This paper evaluates available data and information on ecological effectiveness of 38 SSE projects undertaken in the Detroit River-western Lake Erie watershed over the last 14 years and shares lessons learned.

2. Methods

In 2008–2010, a survey of 38 SSE projects in the Detroit River-western Lake Erie watershed was conducted to document experiences, summarize data on ecological effectiveness, and document lessons learned (Fig. 1 and Table 1). More detailed information on these projects is available at: www.stateofthestrait.org.

3. Results

Since 1999, 38 SSE demonstration projects have been implemented in the Detroit River-western Lake Erie watershed, including 29 along the Detroit River, five along the Rouge River, one along the Little River, one along the Frank and Poet Drain, one along a drain on Grosse Ile, and one along the River Raisin (Table 1). In total, $17.3 million (combined U.S. and Canadian currency) was spent on these SSE projects, including 11 in the under $50,000 range, nine in the $51000–$100,000 range, seven in the $101,000–$500,000 range, eight in the $501,000–$1,000,000 range, and three at equal to or greater than $2 million. Each of these projects had at least one of their goals to improve riparian or aquatic habitat, although the primary impetus may have been some other purpose (e.g., stabilize shoreline and enhance habitat – 24 projects; restore a natural shoreline – 4; remediate contaminated sediment and enhance habitat – 2; treat storm water and enhance habitat – 3; restore an oxbow – 2; undertake a “Supplemental Environmental Project” as part of the settlement – 2; and build stream crossing and enhance habitat – 1). Of the 38 SSE projects implemented, only six (16%) had any quantitative assessment of ecological effectiveness. A brief summary of the six is presented below.

In the case of Elizabeth Park – North River Walk in Trenton, Michigan, the shoreline was stabilized with a concrete breakwall in 1910 and stood for over 90 years as a shore protection structure. This breakwall deteriorated and shoreline restored in 2001, including stabilizing the shoreline using SSE techniques and creating two oxbow islands for nursery habitat for fish. Spring gill net sampling performed by U.S. Fish and Wildlife Service during 2007 (J. Boase, personal communication) collected two spawning ready female walleyes (*Sander vitreus*) and 23 adult male walleyes over a 24-h period. No egg deposition was found on egg mats.

Before restoration of the shoreline at Fort Malden in Amherstburg, Ontario, the shoreline consisted of two failing gabion basket sections on the North and South ends with a sheet steel wall in the middle. Restoration was completed in 2004 and included stabilizing 300 m of shoreline and creating an armor rock revetment and offshore deepwater rock/cobble shoals to enhance fish habitat and create lake sturgeon spawning habitats. Spring gill net sampling performed by U.S. Fish and Wildlife Service during 2007 (J. Boase, personal communication) collected three adult sturgeon (*Acipenser fluvescens*) over a 24-h period. In addition, during the spring 2007 1414 walleye eggs/m^2 were collected systematically using egg mats. In fall 2007, using the same methodology, 39 lake whitefish (*Coregonus clupeaformis*) eggs/m^2 were collected, and in spring 2008 1482 walleye eggs/m^2 were collected at this site. Although not quantified, numerous white perch or white bass eggs were also found. This confirmed that at least three species of fish are using the Fort Malden site as spawning habitat.

Prior to restoration at Goose Bay in Windsor, Ontario, the shoreline was severely eroded with sheet steel walls and broken concrete rubble. Restoration activities were completed in 2000 and included reestablishment of a shallow beach area, construction of shore-connected groynes and an offshore shoal, and placement of rock at a steel sheet piling wall. Aquatic plants were introduced in the nearshore area in the spring following construction. Monitoring was performed in 2001 and found that the nearshore areas protected by the groynes were heavily sedimented with organic ooze (20–30 cm). No submerged aquatic plants were found in nearshore areas protected by the groynes (BioLogic, 2002). However, in the mid-embayment area, outside the groyne protected areas, wild celery (*Vallisneria americana*) became established, averaging four plants per 10 cm^2 in random transects. Wild celery density increased to 10 plants per 10 cm^2 in the offshore area. Benthic invertebrate populations were sparse. However, aquatic worms, dominant in the nearshore area pre-construction, were not found in 2001. There was relatively little change in the offshore area from pre-construction conditions, with midge larva (Chironomidae) being the predominant group.

Prior to restoration at McKee Park in Windsor, Ontario, the shoreline was relatively stable with concrete rubble and riprap, but provided little habitat value. Restoration was completed in 2003 and included the protection of the natural shoreline by constructing offshore barriers using large and small quarry rock to reduce high energy currents and, thus improve spawning and nursery habitat for fish, including lake sturgeon. Spring gill new sampling performed by U.S. Fish and Wildlife Service during 2007 (J. Boase, personal communication) collected 8 gizzard shad (*Dorosoma cepedianum*) over a 24-h period. In addition, egg deposition densities were measured, including 1335 walleye eggs/m^2. In fall 2007, seven lake white fish eggs/m^2 were collected and in spring 2008, 147 lake whitefish eggs/m^2, 4 sucker eggs/m^2, and many white perch and white bass eggs/m^2 were measured. This demonstrates that five species of fish were using rock revetments at McKee Park as spawning habitat.

In the 1960s as oxbow in the lower Rouge River in Dearborn, Michigan, was removed as part of a flood control project. With substantial combined sewer overflow and urban storm water controls implemented in the late 1980s and 1990s, community support led to the restoration of this oxbow in the lower Rouge River. Oxbow restoration was completed in 2002. Immediately after oxbow restoration in 2002 and before stocking, 14 species of fish were identified in the oxbow (Wayne County Department of Environment, personal communication). Naturalists also reported diverse wildlife sightings throughout the restored uplands and wetlands, including coyote, fox, raccoon, deer, raptors, owls, bats, ducks, herons, turtles, frogs, etc.

Prior to restoration of the St. Rose Beach Park shoreline in 2000, the shoreline consisted of a vertical concrete retaining wall along the eastern and western shores. Some rock and broken concrete rubble existed at the toe of each wall. Along the central portion of the embayment, there was a small beach area and a failing, asphalt-capped gabion basket retaining wall. Shoreline restoration was completed in 2000 and included the maintenance of a shallow beach area, replacement of the concrete retaining wall with a rock riprap shore and rock placement at the concrete vertical wall. Monitoring was performed in 2001 and a SCUBA survey of the area found small perch (5–8 cm), darters, round goby (*Neogobius melanostomus*), minnows, and sunfish (*Lepomis* sp.) (BioLogic, 2002). The substrate consisted of silty clay overlaid with a shallow layer (3–8 cm) of soft consolidated sediments. Plant growth began in the nearshore area about 15 m offshore at water depths of

Table 1

A survey of soft shoreline engineering projects implemented in the Detroit River-western Lake Erie watershed, 1996–2010 (all Michigan project expenditures are reported in U.S. dollars; all Ontario project expenditures are reported in Canadian dollars, unless otherwise indicated; project numbers correspond to the map numbers presented in Fig. 1). More detailed information on these projects is available at: www.stateofthestrait.org.

Location	Project goals	Project description and cost	Timeframe	Partners	Monitoring
1. BASF Park, Wyandotte, Michigan	Demonstrate use of Elastocoast (Elastomeric revetment that stabilizes shorelines and enhances habitat by increasing interstitial spaces) along the Detroit River shoreline of BASF Park	Stabilized shoreline to a depth of 37 cm with 5-cm crushed limestone bound together with the Elastocoast product; $6000	2008	BASF Corporation, City of Wyandotte	Qualitative
2. BASF Riverview, Trenton Channel, Riverview, Michigan	Remediate a contaminated site, add incidental habitat to steel sheet piling walls, and create one acre of fish spawning habitat	Following remediation of a contaminated site, incidental habitat was added to 366 m of steel sheet piling, and one acre of walleye, small mouth and largemouth bass, and sturgeon spawning habitat was created; $100,000	2007–2008	BASF Corporation	None
3. Blue Heron Lagoon on Belle Isle, Michigan	Restore emergent wetland shoreline and enhance wildlife habitat	Controlled invasive species, planted native species in the upland buffer area, and placed logs along shoreline to provide habitat to native turtles; $34,000	2000	Detroit Recreation Department, U.S. Fish and Wildlife Service, Michigan Sea Grant, and seven other partners	Qualitative
4. Dean Construction Site, LaSalle, Ontario	Naturalize 550 m of shoreline and create a 0.45-ha storm water management system to treat runoff	Restored 550 m of natural shoreline using soft engineering techniques, reestablished 0.55 km of riparian vegetation along the natural shoreline and created a storm water pond to improve the quality of the storm water before it enters the Detroit River; $62,000	1997–1998	Dean Construction, Environment Canada, and Ontario Ministry of Natural Resources	Qualitative
5. Detroit RiverWalk – Stroh River Place, Detroit, Michigan	Build a section of the Detroit RiverWalk in front of Stroh River Place and enhance riparian habitat	Built a 305-m section of the Detroit RiverWalk using a cantilever design with habitat features beneath the cantilevered RiverWalk; $1 million	2006–2007	Detroit Riverfront Conservancy, Stroh Companies, Inc., Omni Hotel, and Tallon Industries	None
6. Detroit River waterfront (between Lincoln and Langlois Ave.), Windsor, Ontario	Restore 500 m of shoreline using soft engineering techniques and enhance fish habitat	Converted old vertical seawalls into gently sloping irregular rock shoreline configurations and enhanced fish habitat by planting native species; $70,000	1998	City of Windsor, University of Windsor, Dean Construction, and Ontario Ministry of Natural Resources	Qualitative
7. Detroit RiverWalk – West of Milliken State Park, Detroit, Michigan	Stabilize the shoreline along the Detroit RiverWalk and enhance aquatic habitat	Stabilized 152 m of shoreline with varying sizes of rock armor stone and enhanced aquatic habitat; $100,000	2003–2004	Detroit Riverfront Conservancy and General Motors Corporation	None
8. DTE's Rouge Power Plant, River Rouge, Michigan	Remove broken concrete and asphalt, stabilize shoreline, and enhance habitat	Reconstructed 61 m of natural shoreline using soft engineering techniques and reestablished a natural riparian buffer made up of four Michigan native plant communities; $30,000	2005	DTE Energy, Nativescape, U.S. Fish and Wildlife Service, Department of Environmental Quality, Michigan Sea Grant, and five other partners	Qualitative
9. DTE's Monroe Plant, Monroe, Michigan	Restore 152 m of natural shoreline and enhance fish and migratory bird habitat	Restored 152 linear meters of the River Raisin shoreline, created a wetland edge and a 5-m-wide upland buffer area where native species were planted; $68,000	2007–2008	Metropolitan Affairs Coalition, City of Monroe, U.S. Fish and Wildlife Service, Michigan Department of Environmental Quality, International Wildlife Refuge Alliance, and eight other partners	Qualitative
10. Ellias Cove, Trenton, Michigan	Remediate mercury, lead, zinc and PCB contaminated sediment from Ellias Cove and restore the shoreline using soft engineering techniques	Removed 88,000 cubic meters of sediment and disposed contaminated sediment in special contaminant cell at Pointe Mouillee Confined Disposal Facility in western Lake Erie and restored shoreline habitat, including nursery habitat for fish; $150,000 for habitat portion	2006	U.S. Environmental Protection Agency, Michigan Department of Environmental Quality, Great Lakes Basin Program for Soil Erosion and Sediment Control, and seven other partners	Qualitative
11. Elizabeth Park Canal Shoreline, Trenton, Michigan	Restore natural shoreline using soft engineering techniques, rehabilitate wildlife habitat and improve water quality in canal	Restored a natural shoreline using soft engineering techniques; reduced erosion and runoff with creation of a buffer zone of native trees, shrubs, wildflowers, and grasses; and enhanced fish and wildlife habitat; $40,000	2007–2008	Wayne County Parks, Nativescape, Michigan Sea Grant, U.S. Fish and Wildlife Service, and International Wildlife Refuge Alliance	Qualitative

Table 1 (*Continued*)

Location	Project goals	Project description and cost	Timeframe	Partners	Monitoring
12. Elizabeth Park – North River Walk, Trenton, Michigan	Stabilize and enhance 183 m of shoreline and enhance underwater fish habitat	Removed a 1910 concrete breakwall from the north end of Elizabeth Park, stabilized the shoreline using soft engineering techniques, and created two oxbow islands for nursery habitat for fish; $1 million	2001	Clean Michigan Initiative and Wayne County Parks	Quantitative
13. Fort Malden Shoreline, Amherstburg, Ontario	Stabilize shoreline and enhance fish habitat by constructing offshore lake sturgeon spawning habitats	Stabilized 300 m of shoreline, constructed an armor rock revetment and offshore deepwater rock/cobble shoals to enhance fish habitat and create lake sturgeon spawning habitats; $290,000	2004	Essex Region Conservation Authority and Parks Canada	Quantitative
14. Frank and Poet Drain, Trenton, Michigan	Streambed, bank, and upland habitat restoration	Excavated and stabilized shoreline, planted emergent wetland plants and created an upland buffer area with wildflowers and prairie grasses; $80,000	2007–2009	Friends of the Detroit River, National Fish and Wildlife Foundation, and seven other partners	Qualitative
15. Gibraltar Bay, Detroit River, Michigan	Restore native plant community and promote education and stewardship	Restored 357 m of shoreline using biodegradable "soil sock" and clean-composted recycled yard waste to create a new aquatic shelf and planted 1400 emergent plants; $80,000	Phase 1: 2003; Phase 2: 2004–2005	Grosse Ile Nature and Land Conservancy, Nativescape, and eight other partners	Qualitative
16. Goose Bay in Windsor, Ontario	Stabilize shoreline and enhance fish habitat	Protected shoreline with riprap and native plantings, and enhanced fish habitat; $205,000	1999–2000	Essex Region Conservation Authority, City of Windsor and Environment Canada's Great Lakes Cleanup Fund	Quantitative
17. Intrepid Pond at intersection of Intrepid and Meridian at the Commerce Park, Grosse Ile, Michigan	Restore storm water retention basin, create native plant community shoreline, and promote education and stewardship	Removed invasive plant species such as *Phragmites australis* and Eurasian milfoil (*Myriophyllum spicatum*), planted native wetland plants along the shoreline, and created an upland buffer with native bushes and trees; $7000	2008–2010	Grosse Ile Nature & Land Conservancy, Alliance for the Great Lakes, Freshwater Future, and Ford Motor Company	Qualitative
18. Lake Muskoday on Belle Isle, Michigan	Control erosion and enhance shoreline habitat	Stabilized shoreline using soft engineering techniques, removed invasive plant species such as *Phragmites australis*, and planted native wetland plants, shoreline plants and seeds; $30,000	2000–2001	Detroit Recreation Department, Greater Detroit American Heritage River Initiative, and five other partners	Qualitative
19. Little River at Twin Oaks, Windsor, Ontario	Stabilize 1150 m of shoreline, reestablish the natural floodplain, and reestablish the riparian vegetation to improve fish and wildlife habitat	Created a "Natural Channel Design" which stabilized the natural floodplain, planted riparian native species and placed granular stone at bottom of the meandering stream to improve habitat for fish; $1 million	1997–1998	City of Windsor, Essex Region Conservation Authority, Environment Canada's Great Lakes Cleanup Fund, University of Windsor, and five other partners	Qualitative
20. Maheras Gentry Park, Detroit, Michigan	Create an oxbow and restore fish and wetland habitat as mitigation for the construction of Conner Creek Combined Sewer Overflow control facility	Removed 38,300 cubic meters of soil for an oxbow, planted native vegetation to improve fish habitat, and created fish spawning and nursery areas; $2.3 million	2000–2004	Detroit Water and Sewerage Department and Detroit Parks and Recreation	Qualitative
21. McKee Park, Windsor, Ontario	Enhance shoreline habitat and submerged fish habitat for lake sturgeon and other species	Protected 182 m of natural shoreline by constructing offshore barriers using large and small quarry rock to reduce high energy currents and to improve spawning and nursery habitat for fish; $182,000	2003	Essex Region Conservation Authority, City of Windsor, University of Windsor, and eight other partners	Quantitative
22. Northeast Shore of Fighting Island, LaSalle, Ontario	Stabilize shoreline and enhance aquatic habitat	Shoreline sinuosity was increased by constructing limestone groynes along the shoreline that increased stability and enhanced habitat; $60,000 (U.S.)	1996	BASF Corporation and Essex Region Conservation Authority	None
23. Northwest Shore of Fighting Island, LaSalle, Ontario	Demonstrate use of Elastocoast (Elastomeric revetment that stabilizes shorelines and enhances habitat by increasing interstitial spaces) along the Detroit River shoreline of Fighting Island	Stabilized shoreline to a depth of 37 cm with 5-cm crushed limestone bound together with the Elastocoast product; $6000 (U.S.)	2007	BASF Corporation	Qualitative

Table 1 (*Continued*)

Location	Project goals	Project description and cost	Timeframe	Partners	Monitoring
24. Refuge Gateway Shoreline along the Trenton Channel of the Detroit River, Trenton, Michigan	Stabilize shoreline using soft engineering techniques and restore coastal wetland and upland buffer habitats	Stabilized the shoreline using soft shoreline engineering techniques and restored 4.2 ha of emergent marsh, 1.7 ha of submergent marsh, and 4.8 ha of upland buffer habitats; $746,000	2010	Wayne County, Michigan Department of Natural Resources and Environment, U.S. Fish and Wildlife Service, Metropolitan Affairs Coalition and five other partners	Qualitative
25. Rouge River at Fairway Park, Birmingham, Michigan	Stabilize shoreline using soft engineering techniques, manage woody debris, create a native buffer zone, and remove invasive species	Stabilized two separate 15-m lengths of stream shoreline, planted a buffer zone of native plants approximately 8 m wide above the bank at both sites, and removed invasive species along the central wooded area between the two plantings; $30,000	2006	Friends of the Rouge and City of Birmingham	Qualitative
26. Rouge River at Ford Field, Michigan	Stabilize eroding stream banks along lower Rouge River and enhance wildlife habitat	Stabilized 274 m of streambank using soft engineering techniques (using a live fascine, a brush mattress and a vegetative geogrid), installed rock toe, and planted native species and wildflowers; $108,000	1998–2000	City of Dearborn, Friends of the Rouge, U.S. Environmental Protection Agency, Ford Motor Company, and four other partners	Qualitative
27. Rouge River at Hines Park, Michigan	Stabilize eroded stream banks and improve fish and wildlife habitat	Stabilized ten severely eroded sections of streambank along 70 m of shoreline using soft engineering techniques and enhanced 11 ha of fish and wildlife habitat; total for all ten sites: $780,530; average per site: $78,000	2003–2004	Wayne County Department of Environment and Department of Public Services Parks Division	Qualitative
28. Rouge River at Shiawassee Park, Farmington, Michigan	Stabilize the riverbank with soft engineering techniques manage woody debris, create an adjacent buffer zone of native plants, and enhance aquatic habitat	23 m of the riverbank was stabilized by grading back the bank and burying bundles of dormant shrubs (live fascines) in the bank, planted a buffer zone of native plants approximately 8 m wide above the bank at both sites and removed invasive species along the central wooded area between the two plantings; $10,000	2004	City of Farmington, City of Farmington Hills, Michigan Department of Environmental Quality, Friends of the Rouge, and seven other partners	Qualitative
29. Rouge River Oxbow at Greenfield Village, Dearborn, Michigan	Restore fish and wildlife habitat, including wetlands	Restored 671 m of oxbow shoreline, 1.2 ha of wetlands and 4 ha of uplands; $2 million	Oxbow construction: 2002; fish stocking: 2003	Wayne County, The Henry Ford, Clean Michigan Initiative, and six other partners	Quantitative
30. Solutia Plant, Trenton, Michigan	Stabilize shoreline and enhance habitat	Stabilized berm walls on two existing ponds located on the Detroit River using a variety of limestone riprap to enhance shoreline habitat (in lieu of concrete breakwalls or steel sheet piling); $50,000	2000	Solutia Chemical Company	None
31. St. Rose Beach Park, Windsor, Ontario	Stabilize shoreline and enhance wildlife habitat	Reconstructed shallow beach area, replaced concrete retaining wall with a rock riprap shore, and added fish habitat features; $196,000	2000–2001	City of Windsor and Essex Region Conservation Authority	Quantitative
32. Stream crossing at Humbug Marsh Unit, Trenton, Michigan	Build a stream crossing to connect the Refuge Gateway with Humbug Marsh Unit, including the use of vegetated gabion baskets as wing walls to ensure stability and enhance streambank habitat	Installed a 4-m aluminum box culvert that included $4\,m \times 3\,m$ wing walls and planted seedlings of red osier dogwood and black willow to further increase stability and enhance habitat; $30,000	2008	Navy Seabees, Mid-American Group, NTH Consultants, Logs to Lumber & Beyond Inc., and DTE Energy	None
33. Street-End Parks, Trenton, Michigan	Construct three street-end parks and enhance fish habitat to improve fishing opportunities	Created three pocket parks, stabilized shoreline and rehabilitated habitat in the Detroit River; $816,000	2001–2002	City of Trenton, Clean Michigan Initiative, Michigan Natural Resources Trust Fund, and Michigan Coastal Zone Management Program	None
34. U.S. Steel Shoreline West of Belanger Park, River Rouge, Michigan	Restore 610 m of shoreline and enhance fish and wildlife habitat	Restored 335 linear meters of Detroit River shoreline; created wetlands that provide spawning and fingerling habitat, and created an upland buffer area to provide water quality protection; $211,000	2004–2005	U. S. Steel, Nativescape, and U.S. Fish and Wildlife Service	Qualitative

Table 1 (*Continued*)

Location	Project goals	Project description and cost	Timeframe	Partners	Monitoring
35. William G. Milliken State Park, Detroit, Michigan	Demonstrate innovative storm water management and aquatic habitat rehabilitation	Constructed an innovative storm water retention basin that treated runoff from adjacent neighborhood and rehabilitated shoreline habitat using soft engineering techniques; $1 million	2008–2009	Michigan Department of Natural Resources, Detroit Riverfront Conservancy and Michigan Department of Environmental Quality	None
36. Windsor Riverfront (Langlois Ave.), Ontario	Stabilize shoreline and enhance fish habitat	Created a sloping rock revetment, sloping rock beach and submerged shoal features; planted native species; $800,000	2001	City of Windsor -Department of Parks and Recreation, Essex Region Conservation Authority and Detroit River Canadian Cleanup Committee	Qualitative
37. Windsor Riverfront – Legacy Park (near Caron Ave.) Ontario	Stabilize shoreline and enhance fish habitat	Created a sloping rock revetment, cobble and sand beach, sheltering structures and submerged shoal features; planted native species; $3.4 million	2007	Essex Region Conservation Authority, City of Windsor-Department of Parks and Recreation, and Detroit River Canadian Cleanup Committee	Qualitative
38. Zug Island, at the confluence of the Rouge and Detroit Rivers	Stabilize shoreline of Zug Island and enhance aquatic habitat	Placed recycled bricks from steel plant in front of existing concrete shoreline to create habitat for aquatic life and to serve as a berm to further protect the shoreline from erosion; $10,000	2000	U .S. Steel Corporation	None

25–30 cm. Plant coverage was either sparse or very dense, ranging between 3 and 30% depending on the location within the embayment. At the embayment edge, plant growth was nearly 100%. Plant densities ranged from 9 per 10 cm^2 in the denser growth pockets within the mid-embayment area to 17 per 10 cm^2 throughout the offshore area. Wild celery, Richardson's pond weed (*Potamageton richarsoni*), and water hood (*Nais flexilis*) were the main species found. Benthic invertebrates were dominated by midge larvae and snails in the nearshore area. This reflected a change from aquatic worm dominance observed in pre-construction monitoring. Offshore, invertebrate numbers were reduced compared to nearshore, although midge larvae and snails remained the predominant taxa.

4. Discussion

Of the 38 SSE projects evaluated in this survey, 34 were undertaken with multiple partners, including organizations interested in enhancing or restoring fish and wildlife populations, and their requisite habitat. It was important to involve these scientists and resource managers during the initial project planning to broaden the scope of shoreline restoration to include ecological goals. In the case of the Lake Muscoday shoreline restoration on Belle Isle in Detroit, Michigan, projects leaders involved the Natural Resources Conservation Service's Soil Bioengineering Team to help plan and carry out the restoration. All projects were undertaken as demonstration projects to help attract partners who wanted to learn new

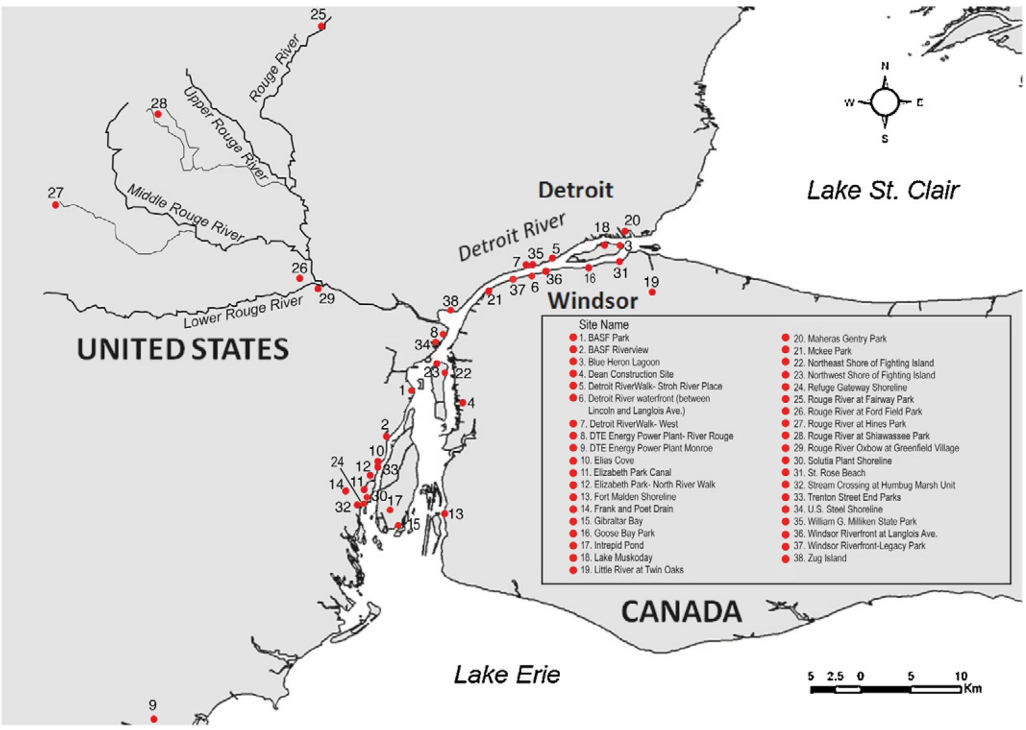

Fig. 1. Locations of 38 soft shoreline engineering projects implemented in the Detroit River-western Lake Erie watershed.

techniques that would demonstrate community benefits. Adding new partners often brought in new resources.

The cost alone of the 38 soft shoreline engineering projects in Table 1 underscores the need for adequate assessment and pre- and post-project monitoring of effectiveness. One way of accomplishing this is to incorporate pre- and post-project monitoring of effectiveness into all federal, state, and provincial permits for habitat modification (Hartig et al., 2010). If not required by permit, it is critically important to reach agreement among partners on a pre- and post-project monitoring protocol to measure ecological effectiveness (Hartig et al., 2010). This could be laid out in a Memorandum of Understanding or a non-binding partnership agreement. Greater emphasis should be placed on attracting university students and involving nongovernmental organizations and conservation clubs to use "citizen science" to monitor ecological effectiveness (Hartig et al., 2010).

Habitat restoration, to a close approximation of its original state or to a desired future state, is experiencing a groundswell of support. The number of river shoreline, streambank, and lakefront restoration projects increases annually. However, far too many projects have been started without clear definition of restoration goals and quantitative targets for success (Covington et al., 1999). Based on this survey of 38 SSE projects, habitat restoration targets and measurable endpoints were lacking. Therefore, greater emphasis should be placed on ensuring a clear, measurable, ecological definition of project success that includes quantifying habitat/ecological targets and objectives that can be used to both evaluate and select appropriate rehabilitation techniques, and to measure project success.

Most of the SSE projects were undertaken opportunistically through a variety of management tools to enhance/improve riparian or aquatic habitat, including: erosion protection, protection of roads, nonpoint source control, Supplemental Environmental Projects (i.e., a regulatory tool that implements an environmental improvement project instead of paying fines and penalties to a general fund), contaminated sediment remediation, improvement of waterfront parks, enhancement of private developments, "greening" projects by industry, and greenway trail projects. However, there is also a need to move beyond opportunistic habitat rehabilitation and enhancement, and achieve scientifically-defensible, ecosystem-based management. This will require greater identification, quantification, and understanding of essential habitats as a prerequisite to successful management of target species and assemblages. Baird (1996) has shown that lack of scientific understanding and institutional problems are major impediments to scientifically-defensible management of coastal habitats. Further, Baird (1996) recognized the enormous management challenge of shifting from managing species/assemblages to managing habitats to support species/assemblages, particularly in an environment of limited resources for research and management infrastructure.

Actions to rehabilitate and enhance degraded habitats should be based on the understanding of causes and predicted results. Adequate assessment, research, and monitoring are essential to define problems, establish cause-and-effect relationships, evaluate habitat rehabilitation and enhancement options, select preferred rehabilitation and enhancement techniques, and document effectiveness. Such assessment, research, and monitoring are the foundation of ecosystem-based management, and, in the end, have often proven to save money for both the public and private sectors (Zarull, 1994).

Based on a review of the six projects with quantitative assessment of ecological effectiveness presented above, four projects had quantitative monitoring that was undertaken opportunistically with no pre-designed plan for monitoring ecological results relative to project goals and objectives. Two of these six projects had quantitative monitoring performed to track ecological results relative to project goals and objectives as part of the pre-designed project plan. The monitoring performed at all six projects was undertaken for only one or two years. Greater emphasis must be placed on strategic monitoring based proper assessment, quantitative target setting, and rigorous post-project assessment of effectiveness as part of an adaptive management strategy (Teal and Weinstein, 2002). Such post-project monitoring should remain in place for some time as recovery may be slow and adjustments to management actions may be necessary (Hartig et al., 2010). Further, there is a need for stronger coupling of habitat modification and, research and monitoring. It would be prudent to treat habitat modification projects as experiments that promote learning, where hypotheses are developed and tested using scientific rigor.

The economic benefits of such rehabilitation work are considerable (Environment Canada, 2004; Austin et al., 2007). Such economic benefits data provide compelling rationale for investing in restoration projects and programs, and can even accelerate habitat restoration. Every effort should be made to communicate and disseminate project benefits and successes broadly through public events and the media.

While SSE is important to improving aquatic habitat, it is also important from a social perspective because it helps reconnect people with the natural world. SSE can be an important element in helping create a much sought-after "sense of place" (i.e., a characteristic held by people that makes a place special or unique; that fosters a sense of authentic human attachment and belonging) on waterfronts in major metropolitan areas. That, in turn, helps contribute to a sustainable community and helps develop additional support for restoration and conservation programs in the Great Lakes and elsewhere.

5. Conclusions

The 38 SSE projects reported on here were undertaken for a variety of reasons and employed a number of different approaches or management tools to enhance/improve riparian or aquatic habitat. All provide "teachable moments" for the value and benefits of habitat enhancement and restoration. Key lessons learned include: involve habitat experts up front in the design phase of waterfront planning; establish broad-based goals with quantitative targets to measure project success; ensure sound multidisciplinary technical support throughout the project; start with demonstration projects and attract many partners to leverage resources; treat habitat modification projects as experiments that promote learning, where hypotheses are developed and tested using scientific rigor; involve citizen scientists, volunteers, and universities in monitoring, and obtain commitments for post-project monitoring up front in project planning; measure benefits and communicate successes; and promote education and outreach, including public events that showcase results and communicate benefits.

Disclaimer

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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