
South Florida Water Management District

FINAL

National Review of Innovative and Successful Coastal Habitat Restoration

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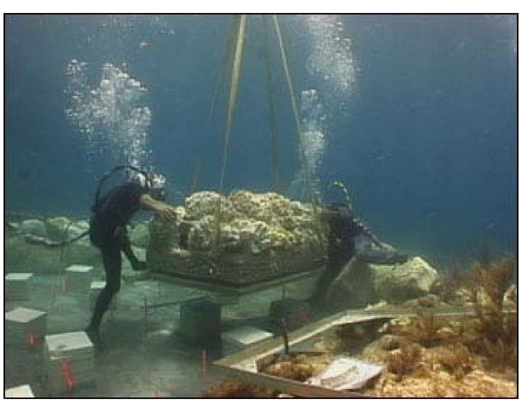
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ABSTRACT

Coastal habitat restoration is a burgeoning science, with numerous organizations participating in an increasing number of projects and programs across the country. Examples of innovative and successful components of these efforts are summarized in this review. The information on projects and programs was collected through expert interviews and through a nationwide review of scientific literature, restoration plans, and Internet sources. The examples provided cover many coastal habitat types from the four coasts of the United States. The review provides information on restoration research and the innovative and successful components of funding, partnerships, planning, restoration methods and techniques, monitoring, adaptive management, information dissemination, and community involvement. The lessons learned from the experiences of the many sources noted in this review are summarized at the end of the paper. Through this work we hope to contribute toward the success of future restoration efforts.

1.0 Introduction

The document, *A National Strategy to Restore Coastal and Estuarine Habitat* (RAE and NOAA 2002), acknowledges that "coastal areas have much to offer one another in terms of innovative and successful approaches to restoration" and stresses the importance of distributing information and lessons learned to others involved in restoration. To that end, the objectives of this review were to find examples of innovative and successful coastal restoration, spanning both the broad geographic area of the coastal United States (U.S.) and the range of coastal habitat types, and to summarize the findings for use by restoration practitioners. This review is part of a larger effort by the National Oceanic and Atmospheric Administration (NOAA) to characterize coastal habitat restoration (see also Diefenderfer et al. 2003).

The *Strategy* discussed above (RAE and NOAA 2002) also puts forth the following seven critical elements for restoring functions to coastal and estuarine habitats: 1) Habitat Restoration; 2) Restoration Partnerships; 3) Restoration Planning and Priority-Setting; 4) Science and Technology; 5) Evaluation and Monitoring; 6) Outreach and Education; and 7) Funding. The topics of this review are similar to those subjects, with two additional subjects discussed, Adaptive Management and Dissemination of Information, drawing from the systematic approach put forward by Diefenderfer and others (2003). In addition, Table 3 of this review provides a summary of innovative and successful restoration methods and techniques. The key findings of this review are provided in the Discussion.

1.1 Background

Coastal habitats are among the most productive and diverse habitats in the world. Types of coastal habitats vary widely across the U.S. and include salt marshes, tidal freshwater wetlands, seagrass meadows, mangroves, unvegetated flats, reefs, and lacustrine marshes (in the Great Lakes area). The loss of these resources has increased tremendously in the past century as a result of direct and indirect human impacts, such as increased development pressures, conversion to agriculture, hydrologic alterations, water quality degradation, global climate change, sea level rise, subsidence, sedimentation, and erosion (Watzin and Gosselink 1992; Hemminga and Duarte

2000; Turgeon et al. 2002; Lewis III 2003a). Restoration efforts in turn have increased in number, scope, scale, and cost. An extreme example is in Louisiana, where over 1500 square miles of coastal wetlands have been lost since 1930 and the costs to implement all the proposed restoration strategies is estimated at $14 billion (Louisiana Coastal Wetlands Conservation & Restoration Task Force & Wetlands Conservation & Restoration Authority 1998). Myriad other cases exist throughout U.S. coastal areas with varying degrees of habitat loss and levels of restoration effort.

1.1.1 Policy Framework

Coastal habitat restoration has been enabled by numerous federal measures. Section 404 of the Clean Water Act requires mitigation for permitted development actions that affect habitat when adverse effects cannot be avoided (2001). Compensatory mitigation can include restoration of degraded habitats. In 1972, the Coastal Zone Management Act (CZMA) was passed and a partnership between federal, state, and local governments was developed to try to balance the often competing and conflicting uses of coastal areas (NOAA 2003a). This partnership, termed The Coastal Zone Management Program (CZMP) has a broad purpose allowing funds to be used for a variety of coastal issues, including restoration. Two recent developments under the CZMP are the development of a habitat restoration network and a wetland restoration tracking program.[1] As part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) of 1980/1986 and the Oil Pollution Act (OPA) of 1990, polluters are responsible for cleanup and restoration of affected resources (NOAA 2003b). Through these legislations, the federal government acts as a trustee for the public to ensure that injured resources are repaired.

Two acts have been passed specifically to address coastal restoration. In coastal Louisiana, the severity of wetland losses led to enactment of the Coastal Wetland Planning, Protection, and Restoration Act of 1990 (CWPPRA) also known as the Breaux Act (USGS 2003a). In 1998, a strategic plan, "Coast 2050: Toward a Sustainable Coastal Louisiana," was developed by federal, state, and local governments (Louisiana Coastal Wetlands Conservation and Restoration Task Force and Wetlands Conservation and Restoration Authority 1998). Currently a comprehensive coast-wide ecosystem feasibility study is being conducted (USGS 2003b). In 2000, the Estuary Restoration Act (ERA) was signed into law in recognition of declining estuarine conditions nationwide. The ERA set a goal of restoring one million acres of estuarine habitat by 2010 and authorized $275 million over 5 years for restoration projects (NOAA 2003c). In addition to the legislation discussed above, Congress has also appropriated funds for restoration in specific regions, for example the Everglades, the Columbia River Estuary, and Puget Sound.

1.1.2 Historical Overview

The science of restoration has been developing over the past 20 years and is becoming a more pervasive element in society. In 1988, the Society for Ecological Restoration (SER) was established and held its first meeting in 1989 (Hughes and Bonnicksen 1990). As of 2003, SER had over 2000 members and it has produced a scientific peer-reviewed journal (*Restoration Ecology*) since 1993 (SER 2003). The number of journal articles related to wetland restoration

[1] For more information contact: Helen Farr, NOAA/NOS/OCRM Coastal Programs Division, (301-713-3105 x150), helen.farr@noaa.gov

has steadily increased since the early 1990s (Turner and Streever 2002). This increase in publications is indicative of the application of science to the field of restoration and the demand for information from practitioners in the field. A recently published book, *The Restoration Economy: The Greatest New Growth Frontier: Immediate & Emerging Opportunities for Businesses, Communities & Investors* by Cunningham (2002), documents a shift from new development to restorative development in both natural and built environments.

Early coastal habitat restoration in the United States was primarily focused on salt-marsh habitat. In a 1981 survey conducted by Knutsen et al. (Broome 1990), the earliest documented plantings of saltmarsh occurred in the 1950s in Virginia to stabilize shorelines. In 1969, the U.S. Army Corps of Engineers funded North Carolina State University to research the feasibility of saltmarsh development using dredged material. This study later incorporated research on eroding shoreline stabilization and techniques for propagation of two *Spartina* species (Broome 1990). Much of the early coastal marsh restoration work was conducted in North Carolina, Chesapeake Bay, Florida, and California as mitigation for coastal development (2000). Coastal restoration in Florida also focused on mangroves. By 1982, 14 mangrove planting projects had been undertaken (Lewis III 1990). More recently in Florida, attention has been given to restoring coral reefs damaged primarily by vessel groundings. Since the 1990s, the approach has been to provide immediate restoration of damaged corals; earlier studies showed that restoration efforts that were not timely proved less successful (Jaap 2000). Restoration of seagrass habitat was documented at a few sites on the east coast as early as 1944 in response to wide-spread losses from wasting disease (Addy 1944). Since the 1970s, seagrass restoration in all parts of the country has received more attention (Davis and Short 1997; Thom 1990). Merkel and Associates (1998) documented 45 eelgrass restoration projects on the North American Pacific Coast between 1976 and 1998.

As interest in coastal habitat restoration continues to grow, the impetus for scientists and managers to convene and share information also increases. The Inaugural National Conference on Coastal and Estuarine Habitat Restoration was held in April 2003 with over 800 participants from every sector of the restoration community. The conference was sponsored by Restore America's Estuaries (RAE), a national nonprofit organization established in 1995 committed to "acting as the cohesive force and guiding beacon for coastal and estuarine habitat restoration across the country (RAE 2002)." Through conferences such as this, the knowledge base is increasing as we are learning from experience and developing new technologies.

1.1.3 Limitations of this Review

The information provided here is not exhaustive, but provides numerous examples of innovative and successful approaches to coastal habitat restoration. Topics not covered in this review include habitat creation, bioremediation, and species restoration (sometimes termed enhancement). Beach nourishment was covered in another characterization study and is also not discussed here.

2.0 Methods

Literature reviews, Internet searches, and surveys of experts were used to gather information for this review. The literature searched was available in Current Contents, referenced in key documents, or recommended by experts. Over 550 citations, including scientific journals, books, technical reports, and conference proceedings, were entered into ProCite, a citation database. Of these, 358 citations spanned the time period from 1998 to present. This review focused on the most recent five years to provide information on the most recent innovations in coastal restoration.

The Internet search was conducted by targeting Web sites known to have information on coastal habitat restoration, connecting to links found on those sites, and conducting keyword searches using various search engines.

The final method of information gathering was through surveying experts in coastal habitat restoration. A preliminary list of known experts was compiled. These individuals were then contacted to gain an overview of restoration efforts in each geographic region and various habitat types. From this overview, additional contacts were made to get more specific information regarding innovative and successful approaches, techniques, projects, and programs.

3.0 Results

The results of our review generally fall into the categories of restoration research or innovative and successful components of restoration projects. First we discuss many examples of restoration research. Second, we provide examples of projects that had innovative components for funding, partnerships, planning, monitoring, adaptive management, dissemination of information, and community involvement and education. Table 3 provides a summary of innovative coastal restoration techniques and methods.

3.1 Restoration Research

Adequate assessment of coastal restoration requires not only a long-term, systematic approach to monitoring, but also a coordinated experimental research program to explain patterns that emerge from the data (Zedler 2001). By incorporating the principles of adaptive management into the experimental approach, scientists can provide information and suggestions that are considered in management decisions (Holling 1978; Walters 1986; Walters and Holling 1990, Thom 1997, Thom 2000). The process suggests corrective measures and can lead to improved restoration results in future efforts in similar ecosystems. In the absence of highly predictable outcomes, restoration sites offer important opportunities to learn by doing. As such, some of the most effective restoration programs integrate pilot studies or experimental designs into their monitoring programs prior to restoration implementation.

3.1.1 Research Organizations and Programs

A number of unique models exist wherein experimental research has become an integral component of successful restoration projects. In general, the ingredients for a successful program include a large funding base, a stable knowledge base (i.e., institutional knowledge), ongoing monitoring programs, and extensive resources for field studies (i.e., labor and equipment). Most often, these circumstances coalesce in a university setting, with leadership provided by a prominent faculty member with a number of supporting graduate students, postdoctoral associates, and collaborators. Often these programs integrate National Estuarine Research Reserve (NERR) support and study sites. Prominent examples include Rutgers University programs involved in Delaware Bay marsh restoration through the Public Service Enterprise Group (Weinstein et al. 1997), and research conducted by San Diego State University's Pacific Estuarine Research Laboratory (PERL) on southern California wetlands under sponsorship of the Earth Island Institute (Zedler 1996; Zedler 2001). Other research institutions involved in coastal restoration research include the following:

- NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina
- U.S. Geological Survey (USGS) National Wetlands Research Center, Lafayette, Louisiana
- National Coral Reef Institute, Fort Lauderdale, Florida
- Oregon Institute of Marine Biology, Charleston, Oregon
- Jackson Estuarine Lab, University of New Hampshire, Durham, New Hampshire
- Virginia Institute of Marine Science (VIMS), Gloucester Point, Virginia
- Wetland Ecosystem Team, University of Washington, Seattle, Washington
- Coastal Research Lab, University of New Orleans, Louisiana.

Several federally funded, nationally and regionally significant programs have been instituted to promote the study and protection of estuarine areas, the development of restoration tools and technologies, and communication and educational outreach. These programs, discussed below, offer opportunities for research, collaboration, and restoration project funding.

The previously mentioned NERR program was established by the Coastal Zone Management Act of 1972 to protect and study estuarine areas through a network of 25 reserves from different biogeographic regions of the United States (NOAA 2003e). One focus topic for the program is habitat restoration (NOAA 2004a). An inventory of restoration activities within the NERR program is currently underway (Crawford 2003).

The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) supports the scientific development of innovative technologies for understanding and reversing the impacts of coastal and estuarine contamination and degradation (CICEET 2003). This research includes finding new approaches for restoring coastal habitats.

The Coastal Restoration and Enhancement through Science and Technology (CREST) program in Louisiana and Mississippi is a research initiative developed through an alliance between NOAA, 11 universities, and the USGS National Wetlands Research Center. The program office opened in 2002, and the first call for proposals is expected in 2003. The goal of the program is to integrate research toward improving coastal habitat restoration through the following:

- better coordination of programs and projects
- assessment and improvement of existing methods
- development of new approaches and modeling
- improvement of tools, communications, and outreach
- increased understanding between scientists, managers, and the public (Chapman 2003).

The NOAA Restoration Research Program, part of the NOAA Restoration Center, was developed to advance the science of restoration ecology in coastal habitats (NOAA 2003f). The program supports research on coastal ecosystem structure and function, and focuses on studying the recovery process of restored coastal habitats, developing and testing innovative restoration methods, and establishing success criteria and monitoring protocols. NOAA staff work in partnership with the scientific community to provide expertise and develop improved restoration techniques.

Various studies organized by habitat type, are discussed in the sections below. The studies were selected because they improve the understanding and methodology of restoration and were presented in the published literature and at scientific conferences.

3.1.2 Salt-marsh Research

3.1.2.1 Hydrological restoration and tidal channel development

Natural hydrology is necessary for restoring functional coastal marshes, and this is often accomplished by returning tidal inundation via breach or removal of barriers such as dikes and levees, or excavation of fill. A recent journal issue (i.e., *Restoration Ecology* Vol. 10, 2002) was dedicated to exploring the potential and pitfalls of dike/levee breach restoration projects, including examination of experimental manipulations that have been useful for designing and evaluating these projects.

The Model Marsh project in the Tijuana Estuary, California, is providing researchers with an opportunity to develop a better understanding of how marsh channels develop following reintroduction of tidal hydrology to a system (Zedler 2001). Tidal channels are one of the most difficult aspects of a system to predict or design. In the Model Marsh, part of the system is divided into two treatments (each replicated three times). In one treatment, channels were dug to mimic what was understood to be natural channel morphology for this type of system. The second treatment allows self-design, in which channels develop naturally under the existing tidal hydrology. The rate, pattern, and morphology of the channels will be assessed through time, along with the role of marsh-plant colonization and fish use.

A number of studies shed light on how hydraulic-geometry relationships and monitoring of physical evolution can assist in the planning of regionally specific tidal wetland restoration projects. Zeff (1999) examines tidal salt-marsh channel morphometry in New Jersey and identifies principles that can be applied to the design and construction of channel networks in tidal-marsh creation and restoration projects. Williams and Orr (2002) analyzes the rate and pattern of evolution of vegetated marsh plains and tidal channels in 15 formerly leveed salt-marsh sites in San Francisco Bay. In this study, vegetation establishment was retarded in sites that had limited suspended-sediment supply, high wind-wave erosion, and restricted tidal exchange. Williams and Orr (2002) also found that formation of marsh tidal channels was greatly dependent on whether and how high the site was filled before breaching, reporting little channel development at high intertidal sites. In a second San Francisco Bay study, Williams et al. (2002) provides hydraulic, geometric relationships for predicting the depth, width, and cross-sectional area of mature tidal channels as functions of contributing marsh area or tidal prism. These relationships can be used to predict the direction and rate of evolution in an immature or perturbed system.

Hydraulic geometry and other indices provide useful guidelines for physical restoration and creation of estuarine tidal channels but do not clarify the ecological consequences of channel form. To provide this linkage, Hood (2002) investigated whether slough geometry is scaled in parallel with ecological processes, including current velocities, detritus export, organic matter deposition, and benthic community composition. Hood found that organic material in bottom sediment scaled negatively with channel size, as did the abundance of benthic-surface deposit feeders, suggesting that fish-feeding functions could be concentrated in smaller channels or the distal portions of large channels. Similarly, Williams and Zedler (1999) linked fish assemblage composition to channel morphology in a series of restored and natural marsh channels in San Diego Bay. Findings from this study highlight the importance of choosing proper assessment criteria and reference sites to avoid misleading interpretations of restoration success.

Restoration of tidal hydrology should proceed with caution in some situations because biogeochemical processes that mobilize nutrients and other elements can have temporary detrimental effects to water quality, soil nutrient levels, and plant vigor. For example, salt-marsh cores from diked and ditched salt marshes in Cape Cod, Massachusetts, were exposed to experimental treatments in greenhouse mesocosms (Portnoy 1999). This study found that salination of drained peat increased porewater pH, ammonium, and iron, and caused increased sulfate reduction that led to significant subsidence and decreased vigor of transplanted *Spartina alterniflora*.

3.1.2.2 Elevation manipulation

In a study by Cornu and Sadro (2002), the marsh surface of a diked and subsided estuarine wetland in Coos Bay, Oregon, was manipulated to examine structural and functional recovery at three intertidal elevations. Results demonstrated that marsh surface elevations subsided at all three treatments, primarily as a consequence of fill consolidation, with vertical sediment accretion driven largely by marsh vegetation density. Tidal-channel development was influenced by marsh surface gradient as much as by marsh surface elevation.

The use of dredged material has been used in numerous ways to offset marsh deterioration or to create proper elevations for marsh creation. For example, to offset the decrease in marsh elevation in North Carolina due to sediment deficits and sea-level rise, a thin layer of dredged material was applied using high-pressure spray dredging (Leonard et al. 2002). The dredged material was added such that the thickness of added sediment ranged from 0 cm to 10 cm in four 40 m^2 plots of both deteriorating and non-deteriorating marsh. The results of the study indicate that both plant stem densities and microalgal biomass increased with the addition of sediment. Their study also suggests that further research is needed to determine an upper limit for the effective thickness of added sediment. Another project using high-pressure spray dredging was effectively employed in Louisiana on a larger-scale plot (0.5 ha) to offset wetlands losses due to subsidence (Ford et al. 1999). The dredged material was applied to both vegetated marshes and shallow water areas adjacent to marshes (i.e., previously vegetated marshes). The results showed that the material enhanced vegetative cover in the marsh and emergent vegetation growth in the shallow water areas. However, shallow subsidence and erosion were concerns in the shallow water areas.

In the Sonoma Baylands restoration project, California, dredged material was used as a supplement to subsidence in previously diked marshes (Marcus 2000). The study estimated that the use of dredged material reduced the time needed for habitat development by several decades. Dredged material is also currently being used successfully in technologies such as geo-textile stabilization tubes, marsh terracing, barrier-island creation, shallow-water enhancement (see Section 3.4 for more information).

The effectiveness of using dredged material for creating or restoring salt marshes has been evaluated in numerous studies. For example, in southwest Louisiana wetland structural characteristics were compared in three natural and four created marshes ranging in age from 3 to 19 years (Edwards and Proffitt 2003). This study found that as created marshes age several structural characteristics approach the levels found in natural marshes. Specifically, vegetation species composition was similar to those found in natural marshes within a few years and also developed along a predictable successional path. However, the percent of organic matter and the bulk densities of the soils were quite different than those of the natural marsh and the authors speculate that it may take several decades for the values to be similar to those in a natural marsh. In Galveston Bay, researchers are experimenting with various marsh configurations of dredge-material marshes to evaluate the effect of landscape on functional value (Minello and Rozas 2002; Rozas and Minello 2001).

The use of dredged material in salt marsh restoration poses many advantages, however numerous factors should be considered in determining whether dredged material should be used for restoration. In a study by Edwards and Proffitt (2003) the dredged material was composed of silty clay (30-65% clay) compared to some other dredge-filled created marshes that used sandier substrates. The authors speculate that the higher clay content may contain greater initial nutrient levels and thus may encourage more rapid vegetation growth. Turner and Streever (2002) recommend that the suitability of the dredged sediment be considered during the planning stages of restoration. Specifically, the authors recommend that contaminated sediment should not be used and caution that the use of clays and silts usually require construction of confining dikes.

3.1.2.3 Plant propagation and reintroduction

A common area of experimental research has focused on increasing the establishment, growth, and functional benefits of native salt-marsh vegetation. Soil amendments, including organic matter (e.g., composted kelp and municipal sewage sludge) or inorganic fertilizers (e.g., urea or ammonium nitrate), are experimental treatments that have been used in restoration sites with coarse soils, such as dredge spoils or sandy upland areas, where nitrogen is limiting (Callaway 2001). Boyer and Zedler (1999) found nitrogen additions increased *Spartina foliosa* growth in the short-term, but few long-term impacts on aboveground growth. Added nitrogen also promoted growth of the annual, *Salicornia bigelovii,* over *S. foliosa* (Boyer and Zedler 1999), although it did not appear to promote accumulation of soil organic matter or nutrients in the long-term (Boyer et al. 2000). Preliminary findings in other ongoing studies have suggested that organic matter amendments, such as alfalfa, peat, kelp, or sewage, may “jumpstart” the marsh food chain by encouraging greater microbial growth (Levin and Currin 2002). Soil enrichment and propagation techniques compared in Seal Beach, California, to test establishment of pickleweed (*Salicornia virginica*) suggest that pickleweed mulch rototilled into the soil increases establishment over transplanting and cuttings (Disney and Miles 2000).

The use of seedlings continues to be an effective approach for establishing diverse salt-marsh vegetation in smaller restoration projects. Empirical studies have compared the effects of species diversity on ecosystem function (Sullivan 2001; 2001). Findings from these studies support the general hypothesis that diversity is important in southern California marsh restoration sites, with high-diversity plantings resulting in more complex canopies, increased biomass, and increased nitrogen accumulation. In a study by Lindig-Cisneros and Zedler (2002), natural seedling recruitment was evaluated in a restored salt marsh as a function of established plant-species diversity. Abiotic effects (i.e., elevation, salinity, and canopy cover) preceded biotic interactions in determining recruitment early in marsh development, although species richness did have a scale-dependent effect on overall recruitment. Results from this study indicate that natural dispersal of seeds at a restoration site can be maximized by introducing tidal inundation in early winter before all seeds have dropped, when high spring tides could disperse seeds, and when rainfall might lower salinities and enhance germination.

Researchers in southwestern Louisiana have evaluated the genetic diversity of native plant species that have been allowed to recolonize large expanses of mud flats constructed from dredged sediments (Travis et al. 2002). The study was conducted on three restored marshes with ages of 1, 4, and 14 years at the time of sampling. Overall, they found that restored populations of *Spartina alterniflora* maintained levels of genetic diversity comparable with natural populations. The researches also theorize that natural recolonization may actually stimulate an increase in genetic diversity relative to natural marshes occupying neighboring sites.

Biotechnology and classical plant improvement methods are currently being evaluated for use in salt-marsh restoration activities through cooperative efforts of scientists from Louisiana State University and the U.S. Natural Resources Conservation Service (NRCS). The objectives of the program are to develop a seed-based system of propagating *Spartina alterniflora* over large areas and to genetically improve the performance of this species (Harrison et al. 2001). Specific ongoing research efforts are focusing on seed encapsulation techniques and evaluation of clones with high seedling vigor and exceptional resistance to disease (Croughan et al. 2002).

3.1.2.4 Functional Assessment

Research on monitoring methods often is focused on determining the functions provided by a restored habitat and comparing the functions to those provided by natural systems. The discussion below is primarily focused on the various functions that salt marshes provide for fish. Other functional assessments can include the use of habitat by birds and mammals, the production of invertebrates, the ability to improve water quality, or the reduction in shoreline erosion.

One novel method to assess ecological function is through the evaluation of bacterial activity in transforming organic matter into available forms for secondary consumers. Researchers have found that bacterial growth efficiency (BGE) is an indicator of ecosystem function, where pristine marshes have the highest BGE (del Giorgio and Newell 2002). The researchers conducted long term monitoring of BGE in both natural and restored marshes and determined that restored marshes have a lower BGE then natural marshes. While there may be a trend in restored marshes toward the values observed in natural marshes, the restored systems continued to have a lower BGE over the six-year study period. These results suggest that there are considerable differences in elemental and organic carbon cycling between restored and natural marshes.

Studies often monitor both the opportunity for fishes to access restored habitats and the capacity of these habitats to promote fish resilience and production (Simenstad and Cordell 2000). Most research has shown that restoration of tidal flows in previously restricted salt-marsh habitats result in rapid changes in the composition, density, size, and distribution of fish and crustacean species (Able et al. 2000;Raposa 2002) although the degree of tidal restriction may also influence parameters of community composition (Raposa and Roman 2003). In some cases, assemblage development may peak soon after restoration, then later decline as sediment and hydrologic processes of a site change and stabilize (Williams and Zedler 1999; Williams and Desmond 2001). In other cases, assemblage structure may be relatively simple in terms of species richness and trophic composition immediately after restoration, and may take a decade or more to approach more natural systems (Simenstad and Thom 1996; Warren et al. 2002).

Landscape characteristics within the marsh can also effect marsh function for fish access and use. Research in Texas and Louisiana continues to assess habitat values for fishery species of dredged material marshes in various landscape configurations using terracing(Minello and Rozas 2002; Rozas and Minello 2001). This method of salt marsh restoration involves the creation of ridges in some pattern that maximizes intertidal edge and minimizes fetch between ridges, with the intertidal areas planted with marsh vegetation. The researchers found that while the terrace marsh was not functionally equivalent to the natural marsh for fishery species, the terrace field supported higher standing crops of most fishery species compared with shallow marsh ponds of similar size (Rozas and Minello 2001). The study recommends that future terracing projects should increase the proportion of marsh in a terrace field to enhance the habitat value for fishery species. In Chesapeake Bay, ongoing studies have started to evaluate whether different planting configurations of *Spartina alterniflora* in restored areas of Eastern Neck National Wildlife Refuge influence access to the marsh surface by fish (NOAA 2003g).

Empirical studies are increasingly being used to confirm the value of restored salt-marsh habitats in terms of realized survival and growth to fishes. Miller and Simenstad (Miller and Simenstad 1997) detected no significant differences in the relative growth of juvenile Pacific salmon in a created estuarine slough as compared with a natural reference site using fish otolith microstructure. In Delaware Bay, an intensive mark-and-recapture program with coded wire tags determined that growth and production of mummichog (*Fundulus heteroclitus*) appeared higher in a restored marsh than in previous studies in natural marshes (Teo and Able 2003). Bioenergetics models that estimate growth of fishes under various conditions (Gray et al. 2002) (e.g., temperature and other physicochemical measurements during fish occupation) have also been proposed as a tool for designing coastal wetland restoration projects (Madon et al. 2001). Researchers at the University of Washington are currently using these mass-balance models to determine how estuarine marsh habitats in different stages of recovery contribute to the growth of juvenile salmon (Gray 2003).

Food-web relationships and fish feeding have also been explored in empirical studies that examine the functional benefits of restored salt-marsh habitats. As with the previous studies, results vary by site. Tupper and Able (2000) found that creek utilization and diets of striped bass were similar between natural and restored Delaware marsh habitats. However, juvenile salmonids occupying restoration sites in southwest Washington (Miller and Simenstad 1997) showed diet composition different from what might be expected in natural reference systems. Restoration sites of different age may reflect differences in fish prey and diets as these systems develop and mature (Gray, Simenstad, Bottom, and Cornwell 2002;Simenstad and Cordell 2000). Stable isotope methods developed as a tool for the analysis of food webs in tidal salt-marsh systems (Kwak and Zedler 1997;Page 1997;Weinstein et al. 2000) are also beginning to be used to assess recovery of trophic function in created or restored systems (Levin and Currin 2002).

In summary, these studies indicate that overall restored salt marshes are providing fish access to usable habitat and the systems are functioning to increase growth, production, and resilience of fish populations. However, in some cases restored systems may be structurally and/or functionally different from natural marshes. Continued research will help determine whether improved restoration methods could improve functional equivalency.

3.1.3 Seagrass Research

Seagrass restoration research has evaluated the effects of restoration on seagrass genetics, methods to improve the cost effectiveness of seagrass restoration, and ways to improve the conditions for seagrass growth.

3.1.3.1 Genetics

Several studies have looked at the effects of transplanting seagrasses on genetic diversity in Chesapeake Bay and southern California (Williams 1997; Williams and Orth 1998; Williams 2001). Findings indicate that transplanted beds were not reduced in genetic diversity compared to natural beds and the use of seeds as donor material could improve the genetic diversity of restored areas. In addition, there is a positive association between genetic diversity and propagation. Eelgrass (*Zostera marina* L.) populations with higher genetic diversity developed more flowering shoots, achieved greater seed germination, and had a higher leaf-shoot density.

3.1.3.2 Transplant Methods

Transplanting adult eelgrass plants has been the focus of many restoration efforts (Davis and Short 1997; Fonseca et al. 1998; Calumpong and Fonseca 2001). Recent research has primarily centered on finding more successful and cost-effective techniques. Short (2003) has developed the Transplanting Eelgrass Remotely with Frame System (TERFS). Two hundred eelgrass shoots are tied with biodegradable ties to a 50- by 50-cm, plastic-coated wire frame, which is then dropped into position from a boat. Several weeks later, after the ties have degraded, the frames are removed and the shoots remain in place. Three out of four one-acre sites continue to show an increase in eelgrass shoot abundance after preliminary monitoring, with failure in the fourth attributed to an algal bloom smothering the plants (Short 2003).

Propeller scarring and vessel groundings have caused considerable damage to seagrass beds in Florida. Two methods have been tested to determine an effective means of restoring the damaged areas are 1) the use of sediment-filled tubes and 2) the placement of bird stakes to promote natural fertilization in transplant areas. The use of sediment-filled, biodegradable, fabric tubes to fill propeller scars in seagrass beds was tested to see if they enhance or prevent seagrass recovery (Hammerstrom 2003). Early results indicate that the sediment tubes are an effective means of deploying fine sediment and preventing further erosion in the propeller scars.

The second method tested in propeller-scarred areas is transplanting fast-growing seagrasses in damaged areas among bird roosting stakes (Kenworthy 2003). The theory is that while roosting, the birds defecate into the water where the seagrasses are planted, and *Halodule wrightii*, a colonizing species, uses the nutrients and rapidly covers the damaged bottom. After 1.5 to 2 years, the stakes are removed and the slower growing, climax species reestablish. The idea can be thought of as a compressed succession in which recovery is accelerated by fertilizing the faster growing species that naturally occur but are normally in lower abundance than the climax species, *Thalassia testudinum*. This method was tested against application of water-soluble fertilizers and plant-growth hormones. The results indicated that the fertilizer application technique failed to increase the recovery rate of *T. testudinum* or *H. wrightii*, whereas the bird stakes produced extremely high recovery rates for *H. wrightii* (Kenworthy et al. 2000).

3.1.3.3 Seeds

Recent research has begun to focus on the use of seeds for restoration to reduce costs and promote larger-scale restoration efforts. Researchers at the University of Rhode Island (Nixon et al. 2002) have developed a mechanized underwater seed planter to efficiently plant large areas of eelgrass. The system is comprised of a pump, similar to that used to fill jelly donuts, mounted on a sled that is pulled along the sediment. The seeds are mixed with a planting media then pumped just below the sediment surface. Current research is comparing organic and inorganic planting media to reduce anoxia and increase resulting seed germination (Nixon et al., 2002).

Harwell and Orth (1999) tested the effectiveness of burlap bags (1.0-mm mesh size) to protect seeds from predation, burial, or lateral transport. The results showed that seeds survived better to the seedling stage with protection (41% to 56%) than without protection (5% to 15%). Seeds planted in the laboratory with and without bags had similar seedling survival (50% in both treatments), indicating that predation and transport may be causes for the differences observed in the field trials.

A method for eelgrass restoration that shows considerable promise is being tested by Orth (2003) in Chesapeake Bay. In this large-scale experiment, a total of 9.1 million seeds were broadcast from a boat over 74 one-acre (0.4-ha) plots. Preliminary results showed that the eelgrass plots were visible in aerial photos after eight months. The use of seeds for seagrass restoration will likely be the focus of further research in efforts to decrease the costs of seagrass restoration.

3.1.3.4 Improving light conditions under docks and piers

Improving light under docks is one method of restoring conditions conducive to seagrasses growth. Blanton et al. (2002) compared the relative amount of light produced by deck prisms, solar tunnels, and metal halide lights. Recommendations considered many variables, including the height of the deck above the water surface, maintenance, structural integrity, and costs; the solar tunnels proved to be the best overall alternative. Another study examined the effectiveness of reflective material under a dock to reflect light from the water surface to depths where seagrasses grow (Gayaldo et al. 2001). These results indicated a positive correlation between the placement of the material and improved survival of the seagrass. A study in Florida looked at the use of deck prisms for increasing light under docks in a freshwater system and found a consistently higher percentage of vegetation cover under docks with deck prisms than under those without (McKinney 2001).

In summary, the research discussed above is focused on improving the conditions for seagrass growth and the cost effectiveness of planting techniques. Through these efforts, seagrass habitat restoration is likely to become more successful and able to occur on a larger scale than in the past.

3.1.4 Reef Research

3.1.4.1 Coral reef

One theme that emerged at the International Conference on the Scientific Aspects of Coral Reef Assessment, Monitoring, and Restoration in 1999 (Thomas 2001) was the need to conduct hypothesis-based research into the efficacy of methods for coral-reef restoration and rehabilitation. One method being evaluated is transplanting donor stock, either collected or grown, to natural and artificial substrates. Studies by Rinkevich and others describe the mariculture of clonal coral fragments in protected areas for eventual transplanting to denuded areas of the reef, as well as the transplanting and growth of gravid colonies in the field or the laboratory to increase the diversity of sites restored by transplanting (Rinkevich 1995; Epstein et al. 2001).

The National Coral Reef Institute has several studies under way in South Florida, some located at ship-grounding sites (Gilliam et al. 2003; Glynn et al. 2003; Quinn et al. 2003). These experiments evaluate the use of potential coral-larvae attractants, such as iron additive, $CaCO_3$, and coral transplants to enhance larval recruitment. They also evaluate the effects of structural complexity affixed to Reef Balls™ (i.e., concrete structures) on fish assemblages, and the interaction between fish assemblages and coral recruitment. Monitoring is being conducted at both the transplanted areas and the coral communities from which donor cores were extracted.

The potential benefits of coral transplants are critically evaluated in a global review of projects by Edwards and Clark (1998), which argues that transplanting should be carried out only when natural recovery processes fail. The authors do, however, identify some exceptions to the rule. One key finding of their study is that because branching corals (e.g., *Acropora, Pocillopora*) naturally recruit rapidly but transplant relatively poorly, there is little justification for transplanting. In contrast, massive species (e.g., *Porites, Pavona*) recruit slowly, grow slowly, and transplant well, suggesting that these species make better subjects for transplantation.

3.1.4.2 Oyster reef

Scientists at the Virginia Institute of Marine Science use oyster reef restoration projects to conduct research on reef biology, community development, and trophic dynamics. These studies provide insight into the success of the restoration in mirroring ecological function provided by historically prevalent oyster reefs in Chesapeake Bay. Harding (2001) examined the horizontal spatial and temporal variation in zooplankton community abundance and composition at a restored oyster reef in a Chesapeake Bay estuary as a potential metric of restoration progress over time. Zooplankton communities are an important component of intermediate trophic levels in estuarine food webs. The seasonal abundance patterns and community composition documented at this restored reef site were similar to that observed in other mid- and south Atlantic estuaries.

3.1.5 Mangrove Research

3.1.5.1 Hydrology

An Army Corps of Engineers Wetland Research Program technical note (Lewis and Streever 2000), shows that hydrology is the most critical factor in mangrove restoration, as demonstrated by the reestablishment of all three Florida mangrove species at West Lake near Fort Lauderdale, Florida, in just 78 months after hydrologic restoration without any planting. Research on this and other systems shows that although restoration managers have frequently tried planting first, a better approach is to "determine the causes for mangrove loss, remove these causes, and work with natural recovery processes." Typically, the cause of mangrove loss is altered hydrology, so it is concluded that planting should only be used as a restoration tool when tidal hydrology has been reestablished and if waterborne seeds or seedlings will not reach the restoration site. Only

15 to 30 years are required for self-repair or secondary succession if normal hydrology and propagules from adjacent stands are present, and dense mangrove shrubs can develop within 5 years of plant establishment. Lewis and Streever (2000) provides five steps critical to successful mangrove restoration, which are abbreviated here: 1) understand the ecology of local mangrove species (especially patterns of reproduction, propagule distribution, and successful seedling establishment), 2) understand the normal hydrologic patterns, 3) assess habitat modifications preventing natural secondary succession, 4) design a restoration program to restore hydrology and, if possible, utilize natural recruitment, and 5) plant only if natural recruitment will not meet the objectives of the restoration project. This approach has been successfully applied in the Cross Bayou Mangrove Restoration Site in Pinellas County, Florida, as mitigation for the Tampa Bay oil spill of August 10, 1993, which after 2 years of monitoring was rapidly achieving the performance criteria (Lewis III 2003b).

3.1.5.2 Plantings

Mangrove plantings have typically resulted in monocultures because of the ease with which the propagules of the red mangrove (*Rhizophora mangle*) are collected and transplanted (Gayaldo 2003). Natural regeneration tends to result in a community of mangrove species that more closely represents nearby communities, which may be similar to the original mangrove vegetation in the area (Field 1998). According to Field (1998), only about 30% of mangrove species have been used in planting projects. However, while monoculture is less desirable than a more natural assemblage of species for various ecological reasons, establishing mangroves may be desirable for stabilizing shorelines (e.g. along boat channels experiencing erosion or on the shore of a new dredge-spoil island). Fortunately, species can be allowed to self-sort along environmental gradients during reestablishment of mangroves, without competition from invasive species, because of the limited species pool that is adapted to the extremes of the mangrove environment such as salinity and flooding (Lugo 1998).

In summary, restoration research is an important aspect of restoration. Experimentation should be incorporated in a restoration project or program whenever possible. The results of research efforts are helping to reduce uncertainties associated with restoration, improve the cost-effectiveness of projects, and develop better implementation methods and assessment techniques.

3.2 Funding and Partnerships

As the scope and scale of coastal habitat restoration increase, so too does the cost of such efforts. Legislation, such as the Clean Water Act, Coastal Zone Management Act, CWPPRA, and the Estuary Restoration Act of 2000, has enabled the appropriation of millions of federal dollars for coastal restoration through a wide range of funding programs. A majority of these programs require participation from a variety of groups at the regional, state, and local levels – both public and private. Many funding programs provide matching grants on a competitive basis. Other programs provide low-cost financing for a wide range of water quality infrastructure projects. Many also provide assistance to create and expand sources for public funding. Table 1 lists examples of federal funding programs. Further guidance on federal funding programs that support the restoration goals of the Estuary Restoration Act is provided at NOAA's Estuary Restoration Act Web site (NOAA 2003d). This site provides a searchable database and the document: "Funding for Habitat Restoration Projects: A Citizen's Guide."

Table 1. An example of Funding Programs and Sources for Coastal Habitat Restoration

Primary Sponsor(s)	*Program*	*Description*	*URL*
Federal Programs			
Coastal America	Corporate Wetlands Restoration Partnership (CWRP)	A voluntary public-private partnership to restore wetlands and other aquatic habitats in the U.S. Partners include private industry, the federal office of the Coastal America Partnership (representing 12 federal departments and agencies), state agencies, non-profit organizations, and academia. Industry contributions generally will be matched by federal/state funds on an average 4:1 ratio.	http://www.coastalamerica.gov/text/cwrp.html
Natural Resources Conservation Service	Farm Bill 2002	Wetlands Reserve Program: Provides technical and financial assistance to landowners and tribes to enhance wetlands in exchange for retiring marginal agricultural land. Other programs are also available.	http://www.nrcs.usda.gov/programs/farmbill/2002/
National Oceanic and Atmospheric Administration (NOAA)	Community-based Restoration Program	The NOAA Restoration Center provides matching funds for projects through a competitive review process. Projects are selected based on technical merit, level of community involvement, ecological benefits, and partnership opportunities.	http://www.nmfs.noaa.gov/habitat/restoration
U.S. Environmental Protection Agency and NOAA Fisheries	Five Star Restoration Program	Provides modest funding on a competitive basis to support community-based wetlands restoration. Projects ideally engage five or more diverse partners to contribute funding, land, technical assistance, workforce support, or other in-kind services.	http://www.epa.gov/owow/wetlands/restore/5star/
U.S. Environmental Protection Agency (EPA)	Clean Water State Revolving Fund (SRF)	Each state and Puerto Rico maintain revolving loan funds to provide low-cost financing for a variety of water-quality and estuary management projects. Although most grant programs require cost shares, an SRF loan can cover 100% of project costs with no preliminary cash outlay.	http://www.epa.gov/owm/cwfinance/cwsrf/
U.S. Fish & Wildlife Service	National Coastal Wetlands Conservation Grant Program	Provides matching grants for acquisition, restoration, management, or enhancement of coastal wetlands through a nationwide competitive process.	http://www.fws.gov/cep/cwgcover.html
Other Programs			
National Fish and Wildlife Foundation	Challenge Grants	On a competitive basis, reviews proposed projects, fosters cooperative partnerships and commits combination of federal and nonfederal funds to on-the-ground conservation projects.	http://www.nfwf.org/programs/guidelines.htm
The Trust for Public Land	Conservation Finance Program	Assists land trusts, communities, and states in creating and expanding sources of public funding for land conservation.	http://www.tpl.org

Funding opportunities are not limited to large federal programs, however. Many smaller innovative partnerships have been forged between groups with shared objectives. For example, Save the Bay is providing golf course superintendents of Rhode Island and Massachusetts with technical support and cost-effective, best-management methods to improve not only estuarine ecological functions, but also the aesthetics and playability of golf courses (Save the Bay 2003a). Golf courses represent one of the largest property owners in this coastal zone.

The focus of many restoration funding programs is to increase participation in restoration projects through innovative and creative partnering. According to Corcoran (2002), successful partnerships have three key ingredients:

1. *Collective involvement* – involve everyone with a stake in the project and collaborate on decision-making to ensure successful implementation. Typical partners include government agencies (federal, state, and local), conservation organizations or local citizens groups, corporations, schools or youth organizations, and landowners.
2. *Shared vision* – generate a commonly shared vision to build long-term support.
3. *Measurable goals* – establish clear goals and objectives to measure progress

One large coastal restoration project that exemplifies the key ingredients of partnerships is the Bahia Grande in Texas. The estuary is within the Laguna Atascosa National Wildlife Refuge, but barriers to the natural hydrological processes were created by construction of the Brownsville Ship Canal in the 1930s (Lassen 2003). The range of organizations sharing the vision of returning water and native vegetation and wildlife to the 11,000-acre estuary is extensive, and includes commercial and sports fishing and shrimping industries, school districts, the navigation district, several federal agencies, and nonprofit organizations. All have donated funds or labor and materials to the effort, which will include the construction of channels to permit adequate tidal exchange and the planting of native grasses and the black mangrove (*Avicennia nitida*). These actions will increase productivity and provide important nursery grounds for recreationally and commercially important aquatic species. According to Lassen (2003), a strong partnership is being built to give everyone an opportunity to participate and ensure the restoration of Bahia Grande is a success.

Another example on a smaller scale is the Jimmy-Come-Lately estuary restoration project in Washington State. The project was spearheaded by the Jamestown S'Klallam Tribe to alleviate frequent flooding and enhance salmon runs. The project involved numerous local, state, and federal agencies, local land owners, and nongovernmental organizations. Representatives from these various entities have worked together for years to develop an estuary restoration vision. They have successfully secured the necessary funding, private land, and other resources to implement the restoration plan. Although still in the early stages of implementation, the Tribe attributes these early successes to a solid scientific foundation, a broad collaboration between partners, early public involvement, and a broad funding base (Rot 2003).

Collaborative partnerships can also be important for conflict resolution when varying viewpoints and multiple resource uses are at issue. The Sonoma Baylands restoration project in San Francisco Bay was controversial regarding the use of dredged material for restoration of diked, subsided tidal marsh; however, through a collaborative effort, the project was successfully implemented (Marcus 2000). This collaborative approach resulted in beneficial results for those involved rather than unresolved conflicts among people with diverse viewpoints.

As these examples demonstrate, active participation of all stakeholders is critical to the success of habitat restoration projects. Diverse partnerships allow the pooling of resources and the opportunity to take advantage of the strengths of all sectors – public, private, and academic (Wolf-Armstrong and Spalding 2002). Single individuals or groups can greatly benefit from forming partnerships in order to more effectively implement coastal restoration.

3.3 Planning

Planning efforts range in scale from large, region-wide coastal restoration programs to individual project planning. Examples of large scale planning efforts are provided below followed by a discussion of approaches for restoration planning from different scales.

Several large restoration programs are currently underway across the nation and are at various phases in the planning process. The CWPPRA program in Louisiana developed a restoration plan over a decade ago to address the need to coordinate and integrate restoration efforts in the region. Since that time, 141 projects have been authorized for funding (USGS 2003c). The Chesapeake Bay Program recently enacted the Chesapeake 2000 Agreement, which will guide the next decade of restoration and protection efforts throughout the Bay (Chesapeake Bay Program 2003). The Comprehensive Everglades Restoration Plan (CERP) provides a framework and guidance to restore, protect, and preserve the water resources of central and southern Florida, including coastal areas (CERP 2003). The plan was approved in 2000, will take more than 30 years to construct, and will cost an estimated $7.8 billion. More recently, the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) established a Science Team to oversee the activities involved in studying and planning for restoration in the Puget Sound region (PSNERP 2003).

The document, *A National Strategy to Restore Coastal and Estuarine Habitat* (RAE and NOAA 2002) provides a framework for Restoration Planning and Priority-Setting and also reviews restoration plans from across the nation. The review found many common elements among successful plans including effective partnerships, education and outreach efforts, availability of funds, use of best available technology, implementation of a scientifically sound monitoring protocols, use of defined success criteria, and a standard tracking system. In addition, many of the most successful projects were those that were part of a watershed plan.

Watershed-based or estuary-wide restoration planning is an approach that is applied by many of the large-scale programs discussed above, but that can also be applied to smaller watersheds or estuaries. This approach is recommended in *Principles of Estuarine Habitat Restoration* (RAE-ERF 1999) and is also discussed by numerous others (Lewis et al. 1998; Foote-Smith 2002;Gersib 2002). The National Estuary Program encourages estuary-wide planning in the 28 estuaries involved in the program through their Comprehensive Conservation and Management Plans (CCMPs), which often include goals for restoration (ANEP 2002). Estuary-wide planning can include both restoration required as part of compensatory mitigation (as required for unavoidable impacts to wetlands) and non-regulatory restoration (Fuss 2000;Simenstad and

Thom 1992). This approach can improve the effectiveness of mitigation (2001) and increase the funds available for restoration (Hall 2003).

Diefenderfer and others (2003) developed a systematic approach to coastal ecosystem restoration, which includes a 19-step method for planning restoration projects. This method was originally developed for project-scale planning, but could also be applied to large-scale restoration programs. Another project-scale planning method is the U.S. Army Corps of Engineers Water Resource Council (WRC) six-step planning process (WRC 1983). This method is generally applied to large-scale restoration projects and incorporates analyses of alternatives and sources of uncertainty.

3.3.1 Planning Restoration in Urban Settings

More than 50% of the U.S. population lives on the coast, with a higher growth rate in coastal counties than in the country as a whole (NOAA 1998). The result of this development has been the loss of a high percentage of coastal habitats that were once present in urban areas. Restoration in urban areas presents the following challenges:

- limited sites available for restoration
- limited reference and plant donor sites
- confounding factors, such as poor water quality, chemical contamination, and altered hydrology
- fragmented habitat
- high costs due to land acquisition expenses and the amount of work required to reverse habitat modifications
- differing needs for coastal resources (e.g., economic, cultural, social, recreational, environmental) (Brammeier 2003)
- differing values of local citizens (Ehrenfeld 2000).

However, these challenges are often offset by the following benefits:

- the restored habitat provides pockets of habitat where otherwise there would be none
- additional natural landscapes for urban residents (Ehrenfeld 2000)
- a heightened public awareness of coastal ecosystems (Milano 1999)
- educational opportunities
- public involvement in the restoration process of highly visible projects, resulting in community project stewardship (see Section 3.8 on community based restoration)

Successful restoration planning in urban estuaries requires public involvement throughout the process. The Mowitch restoration project in Tacoma, Washington, for example, included the public in every stage of the planning process from site selection to design, resulting in wide public acceptance of the project (Steger 2003).

Simenstad and Thom (1992) contends that another aspect of successful coastal restoration planning is the incorporation of compensatory mitigation and non-regulatory restoration into an estuary-wide restoration plan. In urban estuaries, this may be particularly challenging because of the number and diversity of jurisdictional entities (e.g., local governments, private organizations, nongovernmental organizations, and federal and state agencies). If achievable, advantages of this approach include stakeholder approval, identification of ecologically significant areas for conservation and restoration, and funding for restoration through mitigation.

Finally, urban restoration represents the perhaps the most critical and challenging situation to use the principles of landscape ecology for choosing a restoration site. A study by Shreffler and Thom (1993) contends that these principles provide the critical link between restoration ecology theory and effective, practical restoration in urban estuaries. In particular the study highlights the need for emphasis on habitat size, shape, accessibility, connectance, and self-maintenance. In addition, restoration site location can also be critical in urban areas. For example, in the highly urban Duwamish estuary, located in Seattle, Washington, habitat restoration has focused around salinity transition zones in the estuary, which provide places for juvenile salmon to acclimate to the changes in salinity as they make the transition from freshwater to saltwater (Simenstad 2003).

While the challenges of urban restoration are many, the importance of habitat restoration in these settings is monumental from an ecological and societal perspective. The ecological importance of projects in urban areas can be disproportional to the size of the project because of the lack of ecological habitat in the surrounding areas. These projects are also highly visible and can influence the public perception of restoration, therefore successful restoration projects in urban settings can increase support for future restoration efforts.

3.3.2 Goal Setting and Success Criteria

A special issue of the journal *Ecological Engineering* compiled invited papers presented at a symposium on "Goal Setting and Success Criteria for Coastal Habitat Restoration" (Wilber et al. 2000). This issue provides information from a diversity of habitats, has a nationwide scope, and covers many parts of the restoration process.

Evaluation of urban coastal restoration success requires criteria that balance both ecological parameters and the urban context (Ehrenfeld 2000). Ecological functions may be secondary to human values, in which case, the functional capacity must be assessed within a framework of social expectations, ecosystem capacities, needs for active management, and values particular to the urban area (Ehrenfeld 2000).

The Florida Department of Environmental Protection has conducted an exercise to test the utility of various success criteria for the restoration and creation of salt marshes and mangroves for compensatory mitigation, with the goal of providing a set of criteria that is both ecologically meaningful and can be implemented within the existing regulatory environment (Redmond 2000). The language describing these "objective, meaningful, and enforceable" success criteria was further refined to ensure its utility in a legal setting (Redmond 2000). The permit timelines are typically short relative to ecosystem development. Covenants, placed on the land as a condition of the permit, are tools that Redmond (2000) recommends to ensure that complex ecosystem functions ultimately develop. The covenant is a document that accompanies the title of the land stating the long-term responsibilities of the permittee and is established by the permittee prior to permit approval.

The goals of mangrove restoration projects have evolved from establishing "persistent vegetative cover," to establishing "functional equivalency," to "ecological restoration" and "ecosystem restoration" (Lewis 2000). Lewis suggests that to achieve greater success, mangrove restoration projects will depend on providing training for all those involved in the planning process, formalizing specific ecologically-based project goals, and developing individual projects within the framework of regional ecosystem-based conservation and restoration plans. Broad criteria for judging success have been summarized as the rate of recruitment of flora and fauna, the closeness to which the new mangrove ecosystem meets the goals, and the efficiency of the project in terms of labor and other resources (Field 1998). Given the absence of generally accepted criteria for goal setting, it is critical that experts be involved throughout the planning and permit process to ensure that ecologically sound goals are set and appropriate restoration design technology is selected to give the project the highest chance of success (Lewis 2000).

A study identifying the potential effects of various coastal restoration measures on fish assemblages found that although the increase in organic inputs associated with mangrove restoration positively affects estuarine and coastal fish assemblages, it has no effect on the continental fish assemblage, which occupies the upper estuary and wetlands (Baran and Hambrey 1998). The findings are important in cases in which target fish species have been identified in restoration goal setting. In another example, the more mobile estuarine front associated with dam removal would negatively affect the coastal assemblage, while favoring both the fish of continental origin through the intensified flood and the estuarine assemblage through increased area of brackish and turbid waters. The study by Baron and Hambrey (1998) shows that with respect to the restoration of fish populations, it is critical to associate the species or assemblage with habitat requirements, yet also to question whether it is individual fish species or multiple species that should be the target.

3.3.3 Modeling

Modeling is a tool that has been used extensively in coastal restoration planning to predict physical, biological, and hydrological changes resulting from restoration efforts. Both numerical models and conceptual models are powerful planning tools which can be used as part of the adaptive management process where field data are fed back into the models to provide verification and a means of evaluating progress toward the goals.

In Louisiana, modeling has been used to determine the optimum amount of freshwater and sediment to divert from the Mississippi River to restore the coastal system (Clairain 2003). Over the next 20 years, diversion projects are expected to create or stabilize over a 400,000 hectares of wetlands (WaterMarks 2003). One project designed to divert water from the Mississippi River to restore wetlands in the Maurepas Basin led to concern that increased nutrient inputs would lead to downstream eutrophication and associated phytoplankton blooms (Lane et al. 2003). Flow distribution from a hydrodynamical UNET model was used to calculate nutrient loadings and retention, to determine if the Maurepas swamps were a suitable location for restoration. The analysis predicted that 90-95% of introduced nitrate – the nutrient of concern – would be assimilated in the wetlands and would therefore not impact downstream water quality.

A geographic information system (GIS) can provide a useful tool in the restoration planning process. To guide a joint federal and state project to restore a 300-ha coastal wetland on western

Lake Erie, an historical analysis was conducted to determine factors that had contributed to the degradation of the wetland as well as physical conditions to be recreated during the restoration process (Kowalski and Wilcox 1999). Large-scale aerial photographs dating from 1940 through 1994 were interpreted to delineate major wetland vegetation types and boundaries of a pre-existing protective barrier beach. These data were digitized using a geographic information system (GIS). The geospatial data were supplemented by paleoecological and sedimetological analyses to identify the relationships between wetland vegetation, water levels, and sediment supply from littoral drift. This enabled project planners to identify the need to construct a dike to replace the protective function of the historical barrier beach, because near term natural reestablishment was unlikely.

In New England, researchers developed the Marsh Response to Hydrological Modifications (MRHM) model as a predictive tool to evaluate various restoration alternatives in restricted tidal marshes (Boumans et al. 2002). The model output provides expected tidal ranges, water discharges, and flood potential for various culvert installation alternatives. The results of the model can be used to determine the correct tidal regime for salt marsh vegetation establishment. In San Francisco Bay, hydrological modeling was conducted as part of a feasibility study to restore approximately 4,000 hectares of inactive salt ponds and associated remnant sloughs and wetlands. Modelers employed one-dimensional and two-dimensional models to characterize existing physical conditions and to simulate the complex flow field in large open ponds, small slough channels, and rivers (Philip Williams & Associates, Ltd. and DHI Water and Environment 2002). This information provided information to compare project alternatives in subsequent phases of the study.

The Comprehensive Everglades Restoration Project (CERP) proposes to increase freshwater inputs from upland sources to re-establish historical estuarine conditions in Florida nearshore environments. A seagrass model modified to include a short-term salinity response function was used to evaluate the effect of various freshwater inputs and the associated decrease in salinity on seagrass species (Lirman and Cropper 2003). The results indicated that *Thalassia testudinum* would continue to be a dominant component of the nearshore except under drastically lower salinity regimes.

The multiple benefits of using ecological models in the planning process for mangrove restoration are described and applied in a recent case study (Twilley et al. 1998). Models can describe expected trajectories of mangrove development under variable conditions at site and regional levels. Thus, models support the establishment of realistic goals with realistic time frames and the selection of critical monitoring variables (Twilley et al. 1998). Models can improve the understanding of the relative effects of ecological and geophysical processes operating at different scales, helping to improve the design, implementation and adaptive management of the project (Twilley et al. 1998). However, the authors stress that models cannot replace field studies and should be considered a complementary tool.

3.3.4 Site Selection

Whenever possible site selection should be carried out as part of an estuary-wide or watershed restoration plan. The Hudson-Raritan Estuary Project uses an iterative process for identifying problems and ecological restoration opportunities in the highly urban estuary (HRE Project

2004). The Comprehensive Restoration Improvement Plan addresses habitat fragmentation by identifying combinations of restoration opportunities in the context of watershed and regional needs rather than just site specific needs and benefits. Site selection and prioritization in the restoration planning process involve three general steps: 1) assessment and characterization of the study area or region, 2) development of site selection criteria, and 3) prioritization of potential sites.

3.3.4.1 Assessment and Characterization

Site assessment involves the collection of information about an area as necessary in order to adequately characterize or describe the past, present, and future conditions. This process can be done over a broad region to determine the best possible locations for restoration sites or the assessment might be at a smaller site-specific scale to determine whether a site would be suitable for restoration. The methods for conducting this phase of site selection can vary widely, depending on available information and the level of effort afforded to characterization. The more information collected for an assessment leads to a more detailed characterization, resulting in better-informed site selection. Useful assessment information includes historical habitat extent, surveys on substrate and vegetation, elevation data, and physical factors controlling habitat development (Dean et al. 2001;Williams and Thom 2001;Williams et al. 2003;Williams 2001). Data may need to be collected specifically for the purpose of determining site suitability. For example, seismic equipment and remotely operated vehicles were used in site selection for coral reef restoration off the coast of Florida (Japp 2003).

If possible, socio-economic information should be included in the characterization. This data can include growth-management data, land use and zoning of surrounding areas, and future build-out scenarios. The extensive resources spent on restoration warrant a complete evaluation of these data sources to ensure that the restored area will not be degraded by future development. The San Pablo Bay Watershed Restoration Study (U.S. Army Corps of Engineers (USACE) 1999) identifies numerous socioeconomic studies to evaluate potential restoration sites including economic analysis, aesthetic considerations, cultural investigations, and real estate studies.

The use of geographic information systems (GIS) is instrumental in integrating dissimilar data into a manageable decision-making tool. GIS also incorporates elements of the landscape, such as the type and impact of land uses adjacent to the site and the position of the site within the watershed. Numerous entities throughout the country are using this method for determining suitable restoration sites. For example, in New Hampshire, a site-selection model was developed to determine the best locations for eelgrass transplanting (Short et al. 2002). The model synthesizes available historic data, conditions required for eelgrass growth, and field measurements using GIS. Efforts are currently underway to incorporate the model into an interactive CD-ROM (Short 2003).

The North Carolina Department of Environment and Natural Resources developed a method for identifying potential restoration and enhancement sites (Williams 2002) using data on wetland type, soils, hydrography, land use, and land cover. The information was developed in layers using GIS to determine locations where conditions existed for restoration. A similar method was described by Gersib (2000) in Washington using wetland inventories and hydric soil data to determine potential sites. The sites were then overlayed on aerial photos to confirm the sites potential. This information was used in conjunction with other information such as wetland function potential, ecological problems in the study area, and community needs.

3.3.4.2 Criteria Development

The second step in the site selection process is the development of specific criteria for restoration sites, such as level of site alteration, proximity to healthy wetlands, and target functions. The criteria will vary depending on the goals for restoration. In addition, conditions of the study area can contribute to criteria development depending on the level of urbanization and types of land uses in the area. Examples of criteria used for restoration site selection can be found in most restoration plans and in *A National Strategy to Restore Coastal and Estuarine Habitat* (Restore America's Estuaries (RAE) and National Oceanic and Atmospheric Administration (NOAA) 2002). Table 2 shows examples of restoration site evaluation criteria from Fidalgo Bay, Washington (Antrim et al. 2003), the Columbia River Estuary (Johnson et al. 2003), and the Peconic Estuary, New York (Peconic Estuary Habitat Restoration Workgroup 2000). Developing measurable criteria helps ensure the accuracy of the prioritization process and the likelihood of success.

3.3.4.3 Prioritization

Site prioritization approaches often include a quantitative or semi-quantitative ranking protocol based on site-selection criteria (e.g., see Table 2). The document, *A National Strategy to Restore Coastal and Estuarine Habitat* (Restore America's Estuaries (RAE) and National Oceanic and Atmospheric Administration (NOAA) 2002) provides a four step approach for prioritizing sites and recommends that separate lists should be prepared for each estuary or region.

Within the CWPPRA program, annual priority lists for restoration projects are formulated with interagency and public involvement (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2001). Proposed projects are assessed and ranked on a number of criteria, including cost effectiveness, longevity, sustainability, risk and uncertainty, supporting partnerships, public support, and support for the CWPPRA Restoration Plan. Projects are also evaluated for environmental benefits using the Wetland Value Assessment, a quantitative, habitat-based assessment that uses historical wetland-loss data and scientific models.

Prioritization is critical to make certain that limited funds for restoration are spent on the best possible sites. The site-selection process helps ensure that sites meet decided upon criteria, are ecologically sound, fit within region-wide plans, and benefit the community.

Table 2. Examples of evaluation criteria for use in selecting restoration sites.

Peconic Estuary, New York	*Fidalgo Bay, Washington*	*Lower Columbia River Estuary, Washington and Oregon*
<u>Ecological</u> - Lost habitat value - Level of degradation - Historical justification - Proposed project size - Habitat contiguity/adjacent land use - Target restoration functions - Promoting landscape habitat diversity - Providing benefit to state-listed species - Proximity to state/local designated areas <u>Logistical</u> - Type of ownership - Relationship to broad planning efforts - Current stage of planning achieved - Committed/leveraged funds - Probability of success - Support from community/user groups - Level of post-restoration maintenance <u>Enhancing public access and awareness</u> - Enhancing commercial and recreational uses - Benefit to commercial recreational species	- Feasibility - Opportunity to improve ecosystem function - Site protection - Potential for sediment deposition/transport processes to support sustained function - Potential to benefit threatened and endangered species - Probability of success - Habitat connectivity - Restore or replace limited habitat - Sustainability of habitat functions - Type of habitat replacement - Timing of implementation	<u>General Criteria</u> - Habitat connectivity - Areas of historic habitat loss - Linkages to reference sites - Passive habitat restoration over creation - Monitoring and evaluation - Community support and participation <u>Specific Criteria</u> Existing Conditions - Size - Complexity - Accessibility - Habitat connectivity Potential Conditions - Potential to conform to natural habitat structure, processes, and functions - Potential for self-maintenance - Potential benefit to nearshore-dependent threatened and endangered species - Potential to substantially improve ecosystem functions

3.4 Innovative Methods and Techniques

As the science of habitat restoration matures, coastal restoration practitioners are developing new and innovative ways to increase the efficiency and success of restoration efforts. These new methods range considerably in their scale of application, from addressing small, site-specific issues, to having a larger, regional or national focus. In salt marsh restoration, for example, organic baffles are being used in New England in low wave-energy environments to stabilize the eroding edges of marshes. In Coastal Louisiana, vegetated terraces are constructed to diminish wave energy, thereby increasing sediment deposition and facilitating marsh growth. Restorers of seagrass in the Florida Keys use biodegradable, sediment filled tubes to promote the recovery of seagrass damaged from boat propellers. To address large-scale seagrass restoration, researchers in Chesapeake Bay are developing methods to harvest viable eelgrass seeds as an alternative to the more expensive method of transplanting mature plants from donor areas. The restoration of oyster reef habitat in Tampa Bay uses a similar approach to methods being used to restore hard bottom and coral reef habitat in Florida's coastal waters. Small, pre-cast concrete balls are placed along seawalls to promote re-establishment of oyster reef habitat and other littoral benthic communities. Also in Florida, large pre-fabricated limestone-covered concrete modules are deployed to restore and enhance coral reef communities. Kelp habitat in Southern California is being restored through a variety of strategies, from cultivation of juvenile kelp in laboratories to opportunistic transplanting of drift kelp. Table 3 summarizes these methods and other innovative techniques found in our nationwide review.

Table 3. Innovative Coastal Restoration Techniques

Innovative Technique	*Project*	*Location*	*Description*	*Contact*	*URL or Citation*
Salt Marsh					
Dike removal	Deep Water Slough Restoration Project	Skagit River, Washington	Dike removal (instead of breaching) to restore tidal hydrology to system	Curtis Tanner, USFWS Curtis_Tanner@fws.gov	http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/deepwater.pdf
Dike removal and experimental elevation adjustment	Winchester Tidelands Restoration Project	South Slough NERR, Oregon	Dike and tidegate removal. Dynamited to create tidal creek. Created experimental marsh mesocosms. See also Section 3.1.	Steve Rumrill or Craig Cornu, South Slough NERR Steve.rumrill@state.or.us	http://www.southsloughestuary.org
Soil amendments	Tijuana Estuary Tidal Restoration Program	Tijuana Estuary NERR, Southern California	Use of different treatments with soils, such as mixing in kelp and organics, and different amendments to see how it affects marsh growth. See also Section 3.1.	Jeff Crook, Tijuana River National Estuarine Research Reserve jcrooks@tijuanaestuary.com	www.tijuanaestuary.com
Terracing	Little Vermilion Bay Sediment Trapping	Vermilion Parish, Louisiana	Construction of a series of vegetated terraces to diminish waves, increasing sediment deposition, and reducing rate of shoreline erosion.	John Foret, NOAA Fisheries John.Foret@noaa.gov	http://www.lacoast.gov
Barrier islands shoreline	Barataria Barrier Island Complex Project	Plaquemines Parish, Louisiana	Use of mathematical modeling to determine placement of dredged material to prevent breaching of island and to create dune, swale, and intertidal marsh.	Rachel Sweeney, NOAA Fisheries Rachel.Sweeney@noaa.gov	http://www.lacoast.gov
Hydrologic Restoration	Black Bayou Hydrologic Restoration	Cameron and Calcasieu Parishes, Louisiana	Use of a self-regulating tide gate to regulate tidal flushing.	John Foret, NOAA Fisheries John.Foret@noaa.gov	http://www.lacoast.gov
High School nursery program	Sea Grasses in Classes	Tampa Bay, Florida (also Chesapeake Bay and Galveston Bay)	Use of Tampa Bay school system to grow salt-marsh grasses in on-campus nurseries to provide a source of wetland plants for large-scale Bay restoration projects.	Peter Clark, Executive Director of Tampa Bay Watch info@tampabaywatch.org	www.tampabaywatch.org
Marsh Renourishment through Dredged Material Disposal	Sediment Recycling	Masonboro Island, North Carolina	Determination of whether placement of dredged material in tidal marshes could be used to offset marsh deterioration. See also Section 3.1.	Lynn Leonard, University of North Carolina lynnl@UNCW.edu	http://people.uncw.edu/lynnl/ciceet.htm

Table 3. Innovative Coastal Restoration Techniques (Continued)

Innovative Technique	*Project*	*Location*	*Description*	*Contact*	*URL or Citation*
Spartina seedling transplant	Field trial of *Spartina alterniflora* seedling establishment in a created salt marsh	Cape Fear River Estuary, North Carolina	Test of survival of greenhouse-grown cordgrass seedlings (grown using various combinations of watering, fertilizer, soil types) under field conditions	David Padgett, University of North Carolina Padgett@uncw.edu or Charles.r.wilson.saw 02.usace.army.mil	
Geo-textile tubes and dredged materials to expand salt-marsh areas	Barren Island Wetland Restoration	Chesapeake Bay (also numerous other locations)	Use of dredged sand to fill polyester geotextile tubes to expand and stabilize shoreline, then filled 11 acres behind tubes and planted with salt-marsh vegetation	Rich Takacs, NOAA Fisheries Rich.Takacs@noaa.gov	http://www.ngs.noaa.gov/PROJECTS/Wetlands/Barren_Is/
Filtration Enhancement Devices (FEDS)	Organic Baffles to Improve Salt-marsh Stability and Water Quality	Great Bay NERR, New England	Use of porous, organic baffles to enhance filtration and reduce resuspension of sediment to stabilize edges of eroding salt marsh.	David Burdick, Jackson Estuarine Laboratory, New Hamphsire dburdick@cisunix.unh.edu	http://ciceet.unh.edu
Great Lakes Marsh					
Water control structure to create barrier beach	Metzger Marsh Restoration	Ottawa National Wildlife Refuge, near Toledo, Ohio	Construction of dike to replace barrier beach with water control structure to maintain hydrologic connection to Lake Erie.	Doug Wilcox, USGS Great Lakes Science Center douglas_wilcox@usgs.gov	http://www.glsc.usgs.gov/science/wetlands/Metzger.thm
Seagrass					
Propogation of donor eelgrass stocks	Clinton Ferry Terminal Eelgrass Restoration	Puget Sound, Washington	Stockpiling of eelgrass from the area of future impact (five-fold increase in population at lab), then transplanting to areas near the site	Amy Borde, Battelle Marine Science Lab, Washington amy.borde@pnl.gov	
Modeling and use of dredged material	Middle Harbor Enhancement Area	Oakland Bay, California	Use of dredged material to create 100+ acres of shallow-water habitat, including eelgrass		
Sediment tubes in propeller scars	Seagrass Restoration in Propeller Scars	Lignumvitae Key Botanical State Park, Florida Keys	The use of biodegradable fabric, sediment-filled tubes to fill propeller scars and enhance seagrass recovery in propeller scars. See also Section 3.1.	Kamille Hammerstrom, NOAA Fisheries Kamille.Hammerstrom@noaa.gov	http://www.seagrass.net/
Bird stakes to increase fertilization	Seagrass Restoration in Propeller Scars	South Florida	Transplanting of seagrasses and fertilization from birds roosting on specially designed roosting stakes. See also Section 3.1.	Judson Kenworthy, NOAA Fisheries Jud.Kenworthy@noaa.gov	http://shrimp.ccfhrb.noaa.gov/~mfonseca/reports.html

Table 3. Innovative Coastal Restoration Techniques (Continued)

Innovative Technique	*Project*	*Location*	*Description*	*Contact*	*URL or Citation*
Seed collection	Guidebook on Collection, Processing, and Storage of Eelgrass Seeds	Developed in Rhode Island, but applicable where seed production is high	Guidebook on seed development, tips for collection, and methods for separation and storage	Stephen Granger, granger@gso.uri.edu	Guidebook available from: Rhode Is. Sea Grant Communications Office Univ. of RI Bay Campus Narragansett, RI 02882-1197 (order P1635)
Seed broadcasting	Seagrass Restoration in Virginia	Multiple Sites in Chesapeake Bay and Delaware Coastal Bays	Broadcasting of seagrass seeds from a boat (planted 41 acres in 2001 utilizing 4.2 million seeds). See also Section 3.1.	Bob Orth, Virginia Institute of Marine Science (VIMS) jjorth@vims.edu	http://www.vims.edu/bio/sav
Mechanical seed planter	Large-Scale, Seed-Based Eelgrass Restoration	Narragansett Bay, Rhode Island	Use of mechanized underwater seed-planter to inject seagrass seeds mixed in gel matrix into sediment.	Scott Nixon, University of Rhode Island snixon@gso.uri.edu	http://ciceet.unh.edu
Bioturbation fences	Great Bay Estuary Eelgrass Mitigation	Piscataqua River Estuary, New Hampshire	Development of method of fencing seagrass transplant plots to reduce bioturbation by green crabs.	Fred Short, University of New Hampshire fred.short@unh.edu	Restoration Ecology, Vol. 6, 1989, pg. 297-302
Transplanting Eelgrass Remotely with Frame System (TERFS)	New Bedford Harbor Eelgrass Ttransplant	New Bedford Harbor, Massachusetts	Perfection of the TERFS method, which uses a reusable frame, protects against bioturbation, and allows for community involvement	Fred Short, University of New Hampshire fred.short@unh.edu	http://shrimp.ccfhrb.noaa.gov/lab/fonseca/guide/chap3.pdf
Kelp					
Integrated kelp restoration program	Southern California Regional Kelp Restoration Project	Southern California (San Diego to Santa Barbara)	1) outplanting of laboratory-cultivated juvenile kelp, 2) use of sporophyll bags to "reseed" barren reefs with *Macrocystis* spores, 3) relocation of sea urchin grazers, and 4) transplanting drift kelp.	Chantal Collier, California Coastkeepers kelplab@cacoastkeeper.org	http://www.cacoastkeeper.org
Mangrove					
Riley encased methodology (REM™) to enhance mangrove restoration and habitat creation.	Mangrove Replenishment Initiative	Central east coast Florida	Mangrove seedlings are encased in PVC tubing to provide protection and support until establishment, enabling restoration of mangrove in high-energy environments where natural recruitment no longer occurs.	Robert W. Riley, Jr. Mangrove Replenishment Initiative riley@mangrove.org	http://www.mangrove.org Mangroves and Salt Marshes (Incorporated into 'Wetlands Ecology and Management' in 2000) December 1999 3(4) :207-213

Table 3. Innovative Coastal Restoration Techniques (Continued)

Innovative Technique	*Project*	*Location*	*Description*	*Contact*	*URL or Citation*
Site construction without planting	Cross Bayou Mangrove Restoration Site	Pinellas County, Florida	Restoration of mangroves without planting, but through engineered site elevations and removal of dredge spoils.	Robin Lewis, Lewis Environmental Services, lesrrl3@aol.com	
Coral Reef					
Reef modules & limestone boulders	Gulfstream Pipeline Offshore & Inshore Mitigation	Tampa Bay and seaward to 130' depth, seaward of Pinellas, Florida	Deployment of large limestone rocks (2.5- to 4.5-ft diameter) and reef modules (consisting of a reinforced concrete slab with a hollow concrete and limestone dome on top), which provide refugia.	Walter C. Jaap, Florida Marine Research Institute wkjaap@worldnet.att.net or Harold Hudson, NOAA Fisheries haroldhudson@noaa.gov	For reef module information: www.sanctuaries.nos.noaa.gov/special/wellwood/restoration
Coral reattachment to reef substrate	C/V Hind Grounding Site	Off Fort Lauderdale, Florida	Reattachment of >300 corals 2 months after grounding. Mapping and monitoring of reattached corals showed 74% live and securely attached. See also Section 3.1.	D.S. Gilliam, National Coral Reef Institute, Nova Southeastern University Oceanographic Center,	http://www.nova.edu/ocean/ncri/projects/hind/index.html
Coral recruitment to artificial reef substrate	U.S.S. Memphis Grounding Site	Off Fort Lauderdale, Florida	Deployment of 160 artificial reef modules (Reef Balls) adjacent to grounding site and treatment with coral larval attractants. Monitoring of coral development and fish assemblage. See also Section 3.1.	T.P. Quinn, National Coral Reef Institute, Nova Southeastern University Oceanographic Center	http://www.nova.edu/ocean/ncri/projects/memphis/index.html
Oyster Reef					
Reef Balls™ at base of sea walls	Seawall Oyster Reef Project	Tampa Bay, Florida	Use of concrete reef balls along seawalls to promote reestablishment of oyster reef and other benthic communities.	info@tampabaywatch.org	http://www.tampabaywatch.org/seawallreef.htm
Use of recycled oyster shell for reef restoration	S. Carolina Oyster Restoration and Enhancement (SCORE)	South Carolina	Restoration and enhancement of oyster habitat by planting recycled oyster shells in intertidal environment with volunteers	Nancy Hadley, South Carolina Department of Natural Resources Hadleyn@mrd.dnr.state.sc.us	http://www.csc.noaa.gov/scoysters

3.5 Monitoring

Monitoring is a critical element of restoration, whereby performance is assessed to determine whether the restoration project is progressing toward the goals of the project. The information gathered from a monitoring program is essential for adaptive management and for developing a greater understanding of restoration ecology. A guide for developing a coastal restoration monitoring plan was recently developed by NOAA: "Science-Based Restoration Monitoring of Coastal Habitats." Volume I is "A Framework for Monitoring Plans under the Estuaries and Clean Water Act 2000" and Volume II provides "Tools for Monitoring Coastal Habitats" (NOAA 2004b). The components of monitoring that are discussed below are those that are innovative or integral to improving the success of a restoration project.

3.5.1 Pre-Restoration Monitoring

Pre-restoration monitoring can be conducted to determine the existing functions as well as provide information on potential restoration endpoints and help develop project goals. For example, monitoring of the existing functions of a degraded *Phragmites australis*-dominated marsh relative to native *Spartina* spp. marshes along the Woodbridge River in New Jersey showed that reintroducing tidal inundation to the restoration site would enhance water quality functions and the development of salt marsh community structure and food webs (Sturdevant and Craft 2002).

Pre-restoration monitoring can also be used to assess the contaminant release potential from restoration actions. The presence of contaminants can pose ecological and human health risks and can also have significant cost implications. At the Willapa River salt-marsh restoration project in Washington State, for example, researchers analyzed physical and chemical properties of soil, sediment, and water samples as well as coliform bacteria levels of the water and resuspended sediment at selected restoration sites and reference sites prior to dike breach and removal (Diefenderfer and Ward 2002). The researchers concluded that this type of evaluation can improve project design and minimize risk to biological organisms at restoration sites with potential contamination.

3.5.2 Standard Monitoring Protocols

Standard monitoring protocols are important in situations where many observers are involved. For example, the California Regional Kelp Restoration Program uses teams of volunteer divers from local California CoastKeeper affiliates for monitoring. The program developed the Kelp Restoration and Monitoring Protocol to provide detailed instructions and training for the volunteers to ensure consistent and accurate monitoring of the extensive kelp restoration program (California CoastKeeper Alliance 2003).

Standard monitoring protocols are also essential where results from many projects are part of a coordinated program. The Commencement Bay Natural Resource Damage Assessment (NRDA) Restoration Monitoring Program in Tacoma, Washington, provides a matrix of established monitoring criteria, including seven physical, twelve biological, and two chemical criteria (Steger 2003). Project managers can select some or all of these criteria to monitor depending on the goals and objectives of the project.

The Great Bay Estuary Eelgrass Mitigation project in New Hampshire provided an opportunity for the development of a new protocol for assessing natural and restored eelgrass sites. Because the protocol can be used with any seagrass species, the researchers developed SeagrassNet, a global seagrass monitoring program. The monitoring protocol, sample field data sheets, data handling instructions, and a manual for scientific monitoring are available through the Internet (SeagrassNet 2003).

3.5.3 Functional Assessment

One popular method for determining restoration success is to compare the functionality of the restored habitat to that of natural habitat. This is complicated, however, by the fact that there is significant variability in both restored and natural systems and the functional parameters that characterize natural coastal habitat are often not well understood. Recent research has contributed to a greater understanding and application of many popular functional assessment tools. For example, stable isotope methods that were developed to analyze food webs in tidal salt marsh systems are now being used to assess the ability of created and restored systems to provide food for target species (Levin and Currin 2002). Bioenergetics models are being proposed as a tool for designing coastal wetland restoration (Madon et al. 2001). These models estimate growth of fish under various environmental conditions and are being used by University of Washington researchers to determine how estuarine marsh habitats in different stages of recovery contribute to the growth of juvenile salmon (Gray, Simenstad, Bottom, and Cornwell 2002). See Restoration Research (Section 3.1) for more information on innovative methods of functional assessment.

3.5.4 Long-term monitoring

3.5.4.1 The CWPPRA example

The restoration plan developed pursuant to CWPPRA requires 1) "an evaluation of the effectiveness of each coastal wetland restoration project in achieving long-term solutions to arresting coastal wetland loss in Louisiana," and 2) "a scientific evaluation of the effectiveness of coastal wetland restoration projects carried out under the plan in creating, restoring, protecting and enhancing coastal wetlands in Louisiana." Thus mandated, funding is provided for the monitoring of each CWPPRA project for 20 years. Coastal Louisiana scientists and technical experts consensually developed standardized protocols for seven categories of monitoring variables: water quality, hydrology, soils and sediments, vegetative health, habitat mapping, wildlife, and fisheries (Steyer et al. 1995). In addition to providing long-term data to look at status and trends, the monitoring program is designed to investigate cause and effect through hypothesis testing, which requires the establishment of paired reference areas (Steyer and Llewellyn 2000).

Monitoring is based on evaluating project-specific goals and objectives. After the initial nine years of monitoring, many CWPPRA projects have met their goals, (e.g., increasing land:water ratios, increasing submerged aquatic vegetation abundance, and reducing erosion) while others have not. Importantly, the data generated from this monitoring approach are used not only to evaluate the effectiveness of the specific project, but also to provide feedback necessary to make active management decisions. For example, water level monitoring at a marsh management project at East Mud Lake showed that elevations of water control structures were set too high, affecting the duration of flooding. The site was resurveyed and structure operations were adjusted. Monitoring of wave reduction behind a variety of demonstration shoreline protection structures at Lake Salvador has provided important engineering design information for future shoreline projects (Steyer 2003).

As the scale of CWPPRA projects has increased over time, finding adequate reference areas has become increasingly difficult. Also, because many of the projects are adjacent to one another, the potential for cumulative, indirect influences on landscape-level processes has increased, making evaluation of individual project effectiveness increasingly difficult. A monitoring program was needed that effectively monitors at the ecosystem level. Hence, a new monitoring program, the Coast-wide Reference Monitoring System (CRMS), was approved for full implementation in 2003 (Steyer 2003). A network or "pool" of reference sites are being established, which will allow for both project-specific evaluations and cumulative evaluations on both a hydrologic-basin and coast-wide level. These reference sites will span the range of variability from disturbed to pristine across the various vegetation habitats of the Louisiana coast. Restoration projects will then be compared with a suite of reference sites to look at habitat change trajectories over time (Steyer et al. 2002). This analysis will provide a means of evaluating the effectiveness of the restoration on the entire coastal ecosystem versus just those areas affected by individual projects.

Through monitoring the science of restoration can be improved by evaluating the progress of systems over time, determining functional roles of restored habitat, and comparing restored systems to natural systems. Research can play an important role in the assessment of restored systems by improving monitoring methods and providing a better understanding of the functioning of restored systems (Zedler and Callaway 2000). Finally, the longer a project is evaluated, the better the understanding of the system trajectories over time.

3.6 Adaptive Management

Because significant uncertainty exists on the effectiveness of habitat restoration, more and more projects are being designed and implemented in an adaptive management framework. Since 1995, the Corps of Engineers has directed that ecosystem restoration be done according to the principles of adaptive management to better ensure attainment of project goals and planning objectives (USACE 1995). A simple definition of adaptive management is "learning by doing" (Walters 1986). More formally, uncertainties about a project are acknowledged in the planning phase and steps are taken to deal with these uncertainties. These measures may include incremental project implementation, experimental studies in subareas of the restoration site, projects run in parallel that differ in one or more condition, and implementation of full projects with the plan to evaluate the effectiveness of a restoration technique. Each of these techniques requires a project be monitored over time. This is done to assess the success or failure of different restoration techniques and determine what remedial action might be required if a restoration effort is not achieving project goals.

Some very large projects, such as the restoration of the Florida Everglades and the CWPPRA program in Louisiana, have embraced the adaptive management approach. The Everglades program has not been implemented as yet, but planners are adapting project designs using results of extensive modeling studies of hydrology to guide restoration planning. The program will use feedback from an extensive, long-term monitoring program to guide restoration, as well as to correct their conceptual model of the system.

The tidal marsh restoration conducted in Louisiana is employing numerous methods (e.g., water diversions using pumping stations, beneficial use of dredged material for marsh creation, and terracing) to restore the Mississippi River deltaic marshes (Louisiana Coastal Wetlands Conservation and Restoration Task Force and Wetlands Conservation and Restoration Authority 1998). The program managers readily admit that the outcomes of these projects are uncertain, and that some of their efforts have met with failure. Their conceptual model shows that the marshes are starved of nutrients and sediment, and that reintroduction of these materials should alleviate some losses. Their basic strategy is to introduce water, nutrients, and sediment into the marshes to promote marsh growth and development. To assess the success of over a hundred projects, they have strategically located monitoring stations. A scientific team meets regularly (annually) to evaluate a selected subset of the projects. The lessons learned are incorporated into revisions and the development of new project plans. This program benefits from a clear understanding of factors that control marsh development from decades of research on these systems, the ability to conduct experiments with untested technologies, a strong monitoring program, and a framework for evaluating the results and incorporating them into future project plans, as well as through modifications to existing projects.

Smaller project examples include those such as the tidal marsh restoration in South Slough, Coos Bay, Oregon and eelgrass restoration at the Clinton ferry terminal in Puget Sound, Washington. In South Slough, restoration of the Winchester Tidelands marsh (8.1 hectares) was set up to provide information on what elevations are best for marsh development. Here, prior to removal of dikes surrounding former tidal marshes, four areas within the marsh were graded to different elevations. Colonization of the areas is being allowed to progress naturally following dike removal. The information gained through monitoring will allow future projects to be built to maximize the rate and pattern of marsh development through manipulation of elevation.

At the Clinton ferry terminal, eelgrass is being restored in bare areas within and adjacent to an existing eelgrass meadow. An initial 2-year research effort partitioned the various sources of eelgrass disturbance from ferry terminals and ferryboat operations. Although it was clear from the research why eelgrass was absent from some of these plots, reasons were not as obvious for others. Because of the uncertainty regarding restoration potential, the plots were given a relative score indicating low, moderate, or high probability of success. Then monitoring was set up to assess the progress of eelgrass development and to evaluate factors contributing to success or failure. In addition, eelgrass was planted under the terminal in an area where glass blocks in the overhead walkway were installed to pass light to support eelgrass. The effectiveness of this method was evaluated and used along with information from other studies to help plan eelgrass restoration near other terminals in Puget Sound. Clinton, therefore, represents a place where the lessons learned from experimental manipulations can be applied to increase the effectiveness of projects elsewhere. For example, light enhancement technologies have been incorporated in dock design in Port Townsend, Washington (Diefenderfer et al. In Press). The results of the Clinton project are presented annually and discussed with resource agency scientists and modifications are made in both the approach to restoration and to the metrics used to evaluate success. Researchers recently realized that total shoot abundance (relative to eelgrass lost from terminal reconstruction) was a better measure of the goal for the project of no-net-loss of eelgrass habitat than was mean shoot density (Southard et al. 2003). Similar to projects in Louisiana, but on a much smaller scale, this program benefits from a focused research program, a monitoring program, and a management framework.

Adaptive restoration is a concept being put into action in the Tijuana Estuary (Crooks 2003). A 8-hectare portion of the 200-hectare area is being restored in an experimental design so that the lessons learned from the smaller area can be applied to the larger restoration project.

The concept of adaptive management - learning by doing - is generally intuitive, however many restoration projects fail to incorporate it in the overall plan. It was developed specifically to provide information where there is uncertainty and a need for a decision-making framework (Thom 1997;Thom 2000). Adaptive management plans should be developed in the planning phase of a project. The principles of adaptive management can be applied at various levels of intensity and using various strategies. The most important element is to learn from the project.

3.7 Dissemination of Information

Often in the past information from restoration projects has not been widely distributed. In a review of mangrove rehabilitation projects by Field (1998), documentation on the many projects existing worldwide was found to be scarce. Disseminating information about restoration projects is vital to learning from past experiences and thereby improving the success of future projects (Hackney 2000). In recent years restoration information has been more broadly disseminated through the use of the internet and through journals and conferences dedicated to the topic. Considerations in regard to disseminating the results of a coastal restoration project include the purpose, audience, timing, and appropriate venues (Diefenderfer et al. 2003). The appropriate venue for disseminating information can include scientific journals, reports, conferences, fact sheets, and newsletters. Below are some examples of innovative methods of disseminating information that we identified in our review.

3.7.1 Use of the Internet

Recently, the use of the Internet to disseminate information about restoration projects has greatly increased. One Web site that came online in 2003 is the NOAA Estuary Restoration Act (ERA) Database (NOAA 2003c). This site provides information on restoration projects from across the country with links to project Web sites that provide further information. Another NOAA Web site that will be coming online in 2004 is a Web site describing coastal restoration monitoring projects from around the US. This site will also be linked to the ERA Web site (Gayaldo 2003). The Association of National Estuary Programs (ANEP) Web site contains a Habitat Loss Technology Transfer Database, which contains information about restoration from many of the NEP sites (ANEP 2004).

In Rhode Island, numerous groups acted in partnership to develop the Rhode Island Habitat Restoration Portal. The purpose of the portal is to “provide data and information about habitat restoration in Rhode Island to the public, federal and state agencies, and nonprofit groups. The focus is on seagrass, riverine (fish runs), and salt-marsh habitats. The objective is to create an information system that can be used to apply for grants, select potential projects, educate the public, and assist the state in restoration planning (University of Rhode Island Environmental Data Center 2003)."

The Florida Department of Environmental Protection (FDEP) has a web portal called the Florida Wetland Restoration Information Center, which has information on restoration projects, funding sources, guidebooks, and a library (FDEP 2003). In southern California, the Southern California Wetlands Recovery Project Information Station provides a searchable database of biological, hydrological, and land-use information for Southern California's coastal wetlands and watersheds. Project summaries are available with contact information, a brief description, and costs (California Coastal Conservancy 2004).

Information on the Internet can also focus on a particular project. For example, in Washington, the Mowitch Restoration Project has a Web site providing a project summary, list of restoration activities, and documents available for downloading (NOAA 2003h).

3.7.2 Other Innovative Dissemination Methods

Other effective means to disseminate information about restoration projects include the use of conventional media. For example, television can used to reach a very broad audience. The Outdoor Channel taped and aired a restoration planting of mangroves in the Indian River Lagoon by volunteers of the Coastal Conservation Association of Florida - Orlando Chapter (CCA of Florida 2004). The program included interviews with chapter members and also featured cord grass being grown by students of Rockledge High School. Videos and compact discs (CDs) can also be used as an information tool, not only to inform but also to provide training. The Tampa BayWatch Bay Grasses in Classes program distributes a video on how to build a wetland nursery to grow salt marsh plants for restoration (Clark 2003). The California Coastkeepeer Alliance provides a CD, entitled "Help the Kelp," which highlights the Regional Kelp Restoration Project. It includes footage on kelp forests and growing juvenile kelp plants in their Regional Kelp Mariculture Facility (California Coastkeepeer Alliance 2003). Press releases in regional newspapers can also be an effective tool to keep the public and local stakeholders abreast of restoration activities.

In summary, information from a restoration project or program needs to be disseminated widely and in as many venues as possible. Only in this way can the science of restoration continue to mature and uncertainties begin to diminish.

3.8 Community Involvement and Education

Dedicating restoration project resources to activities that involve and educate the community can provide a significant return on investment. A variety of approaches can be used that are beneficial and often critical to the success of individual projects, as well as to long-term public support of coastal habitat restoration. The importance of public involvement is evident in the examples discussed below, which are only a small fraction of the community-based efforts being conducted nationwide.

3.8.1 Public Outreach

Outreach programs provide an effective way to gain public support and recruit volunteers. A few examples are discussed below. The Southern California Regional Kelp Restoration Project regularly offers presentations to dive clubs, community centers, and scientific meetings. Media outreach has resulted in project coverage in newspapers, dive magazines, and local television. Volunteer dive teams are an essential component of kelp restoration efforts as they work with biologists to restore, maintain, and monitor the restoration sites. The project also sponsors an annual Kelp Fest to foster public awareness of the importance of kelp forest ecosystems (Collier 2003). The Galveston Bay Foundation (GBF), a nonprofit organization whose mission is to "preserve, protect and enhance the natural resources of the Galveston Bay estuarine system, and its tributaries, for present users and for posterity," has developed two creative outreach programs. Their Bay Ambassadors program uses trained volunteers to take Bay specimens and visual aids to local classrooms, and Speakers Bureau volunteers speak to community groups about GBF's habitat-related projects (Galveston Bay Foundation 2003).

In urban settings, where conflicting land-use needs often make restoration controversial, involving the public from the start may be essential to the successful outcome of a project. In highly urban Commencement Bay, Washington, the Mowitch Restoration Project organizers encouraged the attendees at a public meeting to draw their own conceptual plan. The public was also involved in the selection process, in planting, and in on-site garbage collection. Additionally, a local Indian tribe was involved in naming the site (Steger 2003).

3.8.2 Volunteers

Hands-on restoration activities such as native plant propagation, transplanting, site mapping, and monitoring that utilize citizen volunteers not only stretches project funding dollars, but enables participants to become environmental stewards. The South Carolina Oyster Restoration and Enhancement (SCORE) program uses volunteers to restore oyster habitat by assisting in oyster shell recycling, building new reefs with recycled shells, and monitoring restoration success. To date, over 5000 volunteer hours have been donated. The Chesapeake Bay Foundation developed a Grasses for the Masses program to help restore Chesapeake Bay's underwater grasses. Volunteers receive the necessary equipment and training to grow native underwater grasses from seed in their homes. Following the 12-week growing period, the volunteers then transplant the grasses at predetermined sites (Bieri 2003). "Marsh Bash 1999" (now an annual event known as Marsh Mania) began with the purpose of involving citizens in the restoration of wetland habitat during a weekend event at multiple locations around Galveston Bay. A total of 1500 volunteers participated in this innovative event and planted 14.5 acres of habitat in 2.5 hours (NMFS Habitat Conservation Division 2003).

Volunteers can also be used effectively for long-term monitoring and maintenance. Through their Sound Stewardship Program, People for Puget Sound trains community stewards to identify native and invasive plant species and track their growth at restored sites to determine how successful restoration sites are functioning as habitat for native species (People for Puget Sound 2003).

The examples discussed above represent but a few of the numerous restoration programs and projects around the nation that use volunteers. Sources are available that can provide information to project managers who wish to use volunteers. For example, The Nature Conservancy has prepared a training module on behalf of the NOAA National Marine Sanctuary System that is intended for project managers who will recruit and coordinate volunteers (Enstrom 2003).[2]

3.8.3 Education

Restoration projects also provide unique opportunities to educate a new generation of responsible environmental stewards. Save The Bay of San Francisco provides many educational opportunities, including classroom visits and field programs for middle and high school classes through a program known as Canoes in Sloughs (Save the Bay 2003b). The Bay Grasses in Classes program sponsored by Tampa BayWatch and other coastal groups use local middle and high schools for a wetland nursery program whereby students learn to plant, maintain, and harvest the wetland plants to be used in restoration projects. By educating and involving the student community, Tampa BayWatch teaches the value of a healthy environment and creates an opportunity for hands-on involvement, and in return, receives the benefit of enthusiastic and energetic volunteers. Currently there are 16 schools involved in the program (Clark 2003; Tampa BayWatch 2004). In Chesapeake Bay, a similar program has gained considerable support since its inception in 1998, with more than 250 schools throughout the Chesapeake Bay watershed participating in the program. The program is coordinated by the Chesapeake Bay Foundation and the Maryland Department of Natural Resources (Maryland DNR 2004).

Community involvement, outreach, and education can increase the success of coastal habitat restoration through public support and volunteer assistance. However, the benefits of involving and informing the community go far beyond individual project success by creating environmental stewards in the community and educating future generations on the importance of habitat and restoration.

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[2] More information on this training module can be obtained through Matthew Stout, Director of NMS Education, Outreach, and Volunteer Program, email: matthew.stout@NOAA.gov).

4.0 Discussion

In recent years, efforts to improve the success of coastal restoration have been increasing. Guidelines were outlined in *Principles of Estuarine Habitat Restoration* (RAE and ERF 1999) and were the basis for development of *A National Strategy to Restore Coastal and Estuarine Habitat* (RAE and NOAA 2002). Other guidance is available in the National *Coastal Ecosystem Restoration Manual* (Ridlington 2002) and *Handbook for Restoring Tidal Wetlands* (2001). In addition, (Diefenderfer et al. 2003) put forth a systematic approach to address uncertainties related to coastal restoration. These efforts exemplify the trend in coastal restoration toward a greater understanding of restored systems, improved communication, and better coordination.

Perhaps the most important lesson of this review is that we must learn from our experiences, whether it is from deliberate experimentation or the result of problem solving. Innovation is critical to improving the science of restoration. The science has evolved from early success in planting of vegetation (e.g., Spartina marshes) to more complex and innovative methods. This development has resulted because the models for successful plant establishment did not always work. The most significant gains were the result of assessment monitoring programs that supplied an understanding of the factors affecting success. Although improving the predictability of a project's success is a critical area for research, restorationists have learned that improving success depends on a strategy that can include a multitude of facets. These components vary from improved site assessment and experimental manipulation of the site to test plantings and removal of disturbances. The importance of partnerships for project funding and long-term site stewardship is now widely recognized. Innovations are spread throughout all facets of restoration projects.

We attempted to capture examples of unique and innovative approaches to restoration across most coastal and estuarine habitat types. By doing this, we hope that others can benefit from the application of these unique and innovative approaches. Below we summarize the findings of the review in eight topics that have emerged from our coastal restoration experiences and from the experiences in the hundreds of projects evaluated in this review.

Incorporate experimentation

Several examples show that simple experiments can go a long way in improving the success of restoration projects. Experimentation does not have to be complicated and highly technical. In most cases, simple tests that help decide between two methods may be all that is needed. For example, test planting seagrass to evaluate the suitability of a site can help refine where planting should be carried out. We suspect that experimentation a) is used more often than reported because simple experiments are often not suitable for publications and b) not always used when needed to provide information that would reduce key uncertainties. Experimentation can also be incorporated as an integral feature of a project so that future projects at the site or in the region can benefit from the information. Finally, adaptive management relies on experiments and monitoring, and provides a framework within which experimentation can be incorporated into a project or restoration program.

Plan at the watershed or estuary level
In the past, the restoration site was the focus of attention, with little regard for the broader landscape. There has been a fundamental shift in approach that has proven successful in many areas where the watershed (or other larger-scale ecological unit) is considered in planning restoration at sites. The two basic reasons for this change are: 1) to maintain restoration sites in the long-term, the processes (e.g., hydrology) that control maintenance must be functional in the system; and, 2) if a site is restored to help a certain highly motile species (e.g., migratory fish and birds), but the habitat requirements are inadequate for maintenance of the population at a larger scale, the actions taken at the site will provide little or no benefit for the species. The probability of a site restoration working is improved if the landscape processes are relatively intact (Mitchell 1981; Shreffler and Thom 1993).

Choose appropriate sites
Ultimately, site selection can be summed up in the rule of real estate: "location, location, location." Often in the past, and probably into the foreseeable future, restoration project sites will be those that are presented as an opportunity rather than being selected from among a suite of potential sites using objective, science-based criteria. However, the primary factor explaining project failure is inadequate site conditions. Realizing this, site-selection methods are being developed to improve the process. The best methods appear to be those that rely on the scientific understanding of the requirements (e.g., elevation, hydrology) of habitats, and what must be done to a site to make these conditions correct for the target habitat. Using science-based criteria, the sites can be narrowed to those most likely to prove successful. Other criteria such as land ownership, public opinion, and surrounding land uses can then be factored in to choose the best possible site.

Form creative partnerships
Restoration is generally an expensive endeavor and is driven by the ability to provide adequate financial support for all phases of a project. What restorationists have realized is that to accomplish a project, funding will likely come from a variety of sources in both cash and in-kind contributions. Knowledge of what needs to be accomplished to make a project happen and who might contribute as a partner in the process is a key element of successful restoration projects. As much as scientists tend to shy away from it, politics also can play a key role in a project. Having a wide base of support helps in funding the project, can provide needed expertise and labor, and also helps provide political support.

Identify challenges and set appropriate goals
Setting a realistic and clear goal for a project, while acknowledging the uncertainties and challenges up-front, provides a guide for project success. If there is any consensus in restoration, it is that a clear goal statement is required to direct what is done on a project. A vague or unrealistic goal statement only sets a project up for failure. The simplest projects (e.g., replacing a nonfunctional tide gate with a self-regulating tide gate) that offer obvious benefits can also offer major challenges. The challenges can operate at all levels and scales of intensity from the technical to interpersonal. Realizing these challenges up-front and developing a strategy to deal with them will help smooth the planning and implementation process. Here is where technical experts, community involvement specialists, and politicians can all play a vital role. Rare is the person who can operate at all these levels, although many have tried and have encountered a high

level of frustration and disappointment in the process. Although fighting for a solid project on technical grounds may seem logical and obvious to some, political and interpersonal issues are equally powerful.

Establish long-term funding for monitoring
Monitoring is the basis for improving restoration science. Monitoring in the past often has been either not done or poorly conducted. Monitoring does not need to be complex and expensive to provide critical data needed to manage the project and to help make decisions on alternative actions. Monitoring is critical to applying adaptive management as a framework for restoration. Many innovative methods are published on how to monitor key variables at restoration sites. Funding is required to conduct monitoring in most cases, and the source of funding should be reasonably assured for the long-term. Volunteers have been used successfully and very effectively to monitor routine parameters. Training volunteers, managing the data, and producing summary reports is best handled by a person or group accustomed to doing this. Support for these tasks often requires funding.

Use adaptive management to reduce uncertainty
We can no longer walk away from a project assuming it will work as expected. Most projects do not end up exactly as planned, and many end up quite different than predicted. When projects involve little funding, this may not be an issue, but for projects costing several million dollars, a failure is not acceptable. Many large programs are using adaptive management principles to try innovative and uncertain methods and to learn from these methods. As mentioned above, clear goal statements, acknowledging uncertainties and challenges, and an effective and focused monitoring program are all elements of an adaptive management program.

Involve the community
In the words of Margaret Mead, "Never doubt that a small group of dedicated individuals can change the world. Indeed, it's the only thing that ever has." Community involvement and support was cited in the literature and by those interviewed as a common element leading to successful projects. The community often is the key political force supporting a project, which will drive funding and other aspects of a program (e.g., permits). In addition, the community is an excellent source of stewardship. The community is invested in its region and generally wants to see the area improved. Community members often see restoration as adding value to their property, creating educational and recreational opportunities, and enhancing the overall quality of life.

5.0 Conclusion

In conclusion, restoration projects provide an important opportunity to learn from innovation and the experiences of others. The probability of success can be greatly enhanced through selecting appropriate project sites based on objective, science-based criteria; approaching the project from a broader perspective (i.e., at the landscape level); and being willing to risk taking new and experimental approaches. Restoration is necessarily a combined effort, requiring the contribution of skills and funding from a variety of sources and stakeholders working toward a common goal. These resources are required from the onset of planning through the long-term monitoring stages to the realization of project goals. Challenges are generally the rule, rather than the exception. Establishing clearly defined, realistic goals at the planning phase provides a shared path forward. Adaptive management provides a framework for critical review and decision making to ensure progress toward restoration objectives. Most importantly, it is the collaborative efforts of dedicated scientists, consultants, educators, resource managers, regulators, conservation groups, volunteers, and others that make a restoration project a success. We hope the experiences from the sources noted in this review contribute toward the success of future restoration efforts.

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