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# PERSPECTIVES IN ESTUARINE AND COASTAL SCIENCE

## Linking Restoration Ecology and Ecological Restoration in Estuarine Landscapes

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**ABSTRACT: More than ever, there is a need to integrate restoration ecology, as practiced by the scientific community, and ecological restoration, a province that is largely, but not entirely the purview of practitioners. Success in some coastal restoration projects is increasingly measured in the context of practioner skills and cultural goals rather than by the manifestation of underlying ecological principles and mechanisms in the restoration process. Especially in human-dominated landscapes, restoration practices should attempt to balance human needs with those of extant biota in a consensus based combination of restoration ecology and ecological restoration criteria. The goal is to devise plans at the appropriate scale that allow humans and other biota to share space and resources in an increasingly complex landscape. No matter where restoration takes place, both ecological fidelity (in ecocentric terms) and human dimensions (in anthropocentric terms) must comprise the restoration design, but ultimately in proportion to human density in the landscape. Without this integration, compromise, and balance, restoration will not likely prosper in the mainstream of society.**

### Introduction

There are many criteria for restoring coastal wetlands, but they can be collectively distributed across a spectrum ranging from science-based restoration ecology to society-based ecological restoration. The differences are not trivial and may lead to widely varying goals for the restoration effort. Restoration ecology, the purported myths notwithstanding (Hildebrand et al. 2005), is largely relegated to the scientific practices that underpin restoration goals, trajectories, and end points, and also includes hypothesis testing, observations, and field and laboratory experiments. While sometimes including elements of restoration ecology, ecological restoration may be thought of as the entire sum of practices that address the goals of restoration, including those that encompass the human dimensions: social, political, technological, economic, cultural, and religious (Higgs 2005).

Restoration attempts almost always include a cultural fabric. Higgs (1997) notes that the most transparent view of the cultural significance of restoration efforts rest in the notion of redemption. We heal ourselves culturally and perhaps spiritually by healing nature (in a biblical context we are offered the possibility of absolution), a strong incentive for those racked by guilt over environmental degradation. Ecological restoration may tap cultural values that are widely divergent from scientific rigor. How do we meld the two?

The recent emphasis on culturally induced criteria for ecological restoration has resulted in the two-culture conflict; i.e., distinguishing between the need for scientific rigor and the broader outcomes of restoration based on societal perceptions and desires (Weinstein et al. 2001; Gross 2002; Higgs 2005). If we are not careful, public acceptance and aesthetic reproduction can easily overwhelm the need for ecological fidelity, that combination of structural replication, functional success, and durability (self-sustainability) that scientists desire, especially in the context of ecosystem dynamics (Higgs 1997). Without balancing ecological function with sustainable human practices, ecologists will miss an important constituency if the role of humans in ecosystems is ignored or minimized (McDonnell and Pickett 1993; Swart et al. 2001).

Because nature and ecosystems are historically and culturally contingent ideas, Higgs (1997) also suggests that there is no one single, fixed, correct restoration for any particular site, although structure, composition, and function criteria may provide tight guidelines for success of the project. By Higgs' standards, the definition of good ecological restoration is rooted in ecological fidelity but will also benefit from an expanded context (especially in setting goals and outcomes) by including societal values (economic efficiency and social, historical, political, moral, and aesthetic; see below). The

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cultural element is also critical, not only because incorporating societal values enhances public acceptance of restoration and improves its chances of success, but also because virtually all coastal lands have been influenced by human presence. The fabric of coastal restoration is at once driven by ecological criteria (restore ecosystem function), as well as the likelihood that restoration end points may be something less than pristine, but societally acceptable.

These are not necessarily new ideas. More than 30 years ago, Cairns et al. (1975, p. 522) distinguished between the public perception of restoration practices and scientific knowledge: ''The characteristics of restored ecosystems are bound by two general constraints, the publicly perceived restoration and the scientifically documented restoration. For example, recovery may be defined as restoration to usefulness as perceived by the 'users' of the resource. This is significantly different than restoration to either the original structure or the original function (or both) as rigorously determined by scientific methodology.''

How can public perception and scientific rigor be balanced? Cairns (1995, p. 9) attempted to answer this question with his proposal for ''eco-societal restoration'': ''Because of its interdisciplinary nature, ecological restoration must involve ecosocietal restoration. This is the process of reexamining human society's relationship with natural systems so that repair and destruction can be balanced and, perhaps, restoration practices ultimately exceed destructive practices. Human society's practices are the best indication of its ethos or set of guiding beliefs. Ecosocietal restoration is a positive statement of cooperation with natural systems.''

Cairns' model of ecosocietal restoration forces the recognition that restoration practices manifest societal values. What he is clearly advocating is recognition of mutual interests on the part of restoration scientists or practitioners and the public. Higgs (1997, p. 347) calls this inclusiveness, a ''reasonable balance'' between individuals who are long-term stakeholders; e.g., recreational and commercial fishermen, environmentalists, restoration scientists, restoration consultants, amateur naturalists, landholders, corporations with vested interests (e.g., the project sponsor), and federal, state, and local governments.

By bringing such stakeholders with diverse interests together in new governance system based on integrated coastal zone management concepts (Weinstein et al. 2007) and by providing them with a voice in the conduct of the restorations, constructive discussion, criticism, and negotiation will follow that can only benefit the project. The risks are minimal.

Rather than adopt the National Research Council's context for restoration— the desire to return an ecosystem to a close approximation of its undisturbed state, or the historic condition (NRC 1992)—I suggest that we acknowledge that baselines have permanently shifted in human-dominated landscapes (Weinstein and Reed 2005, p. 176) and embrace the general concept of restoration-rehabilitation as ''renewing an ecosystem's vitality by reuniting its functions,'' but to the extent that is practical as determined by consensus among stakeholders along those highly populated coasts. I agree with others that the traditional view of restoration as activities carried out on a site-by-site basis, should give way to one where restoration occurs on a landscape scale and is an important component of regional planning (Naveh 1994; Hobbs and Norton 1996; Hobbs and Harris 2001).

## The Dangers of Parochialism

By ignoring the concept of ecological fidelity, practioners may find themselves at the mercy of forces that question the validity of what they call restoration. In these instances, it is easy to find these kinds of statements in the published literature: Restoration may ''be seen as a sort of gardening with wild species in natural mosaics'' (Allen and Hoekstra 1992, p. 265); ''is an expensive self-indulgence for the upper classes, a New Age substitute for psychiatry. It distracts intelligent and persuasive people from systematic initiatives'' (Kirby 1994, p. 239–240); and ''To many industrialists and global environmental negotiators. . . ecological restoration appears a fair and benign, Western middle-class, pastoral practice, the kind of activity that harms no one and fills in the gaps among the really big problems'' (Higgs 1997, p. 342).

What is needed is a definition of good restoration that simultaneously rests on clear and necessary performance criteria (our science) and on the knowledge that the worth of restoration is adjudicated in the historical, social, political, aesthetic, and moral contexts (Higgs 1997). If restoration practices hold firm to ecological fidelity and if social and cultural goals are also embraced, then restoration is much more likely to prosper and endure (Higgs 1997). The question in a particular circumstance is how much of each?

I depart somewhat from this approach. In today's world, our ability to set aside any parcel of coastal land for conservation is paramount to the future of the coast. Even if only for purely anthropocentric motives, such as restoring public access or providing an aesthetic experience or recreational area (e.g., the Hackensack Meadowlands in New Jersey), the set-aside of shore lands is important to the future

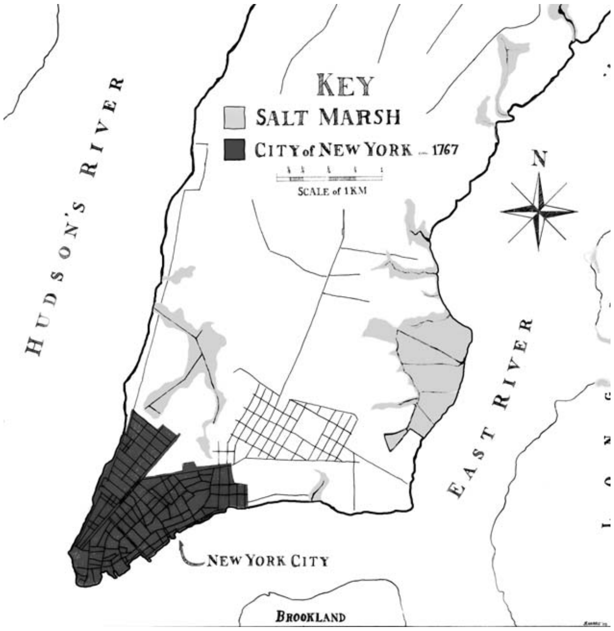


Fig. 1. An engineering survey of lower Manhattan Island in 1767 depicts extensive coverage by wetlands in the area of the modern World Trade Center complex, South Street Seaport, and the United Nations plaza (map provided by U.K. Hydrographic Office, Somerset, U.K.)

sustainability of the coast. Balance will be the key element of any restoration endeavor.

## A Revised Paradigm

Weinstein and Reed (2005) distinguished among restoration versus rehabilitation, biotic integrity versus ecosystem health, and compositionalist versus functionalist approaches to restoration design. The authors also suggested that restoration goals be set according to human density in the landscape and characterized estuarine settings according to their dominance by humans (Weinstein and Reed 2005; Weinstein 2007).

## Urban-industrial Estuaries

Urban-industrial estuaries are estuarine systems whose physiography and geological settings support intense human uses and populations, principally for living space, navigation, marine transportation, and commercial activity related to port commerce, energy production, or other water intensive uses. Because ecological baselines have shifted dramatically in urban-industrial estuaries, concomitant losses in habitat and biodiversity are likely irreversible (Weinstein and Reed 2005). Management priorities in urban-industrial systems focus on reliability criteria (Roe and van Eeten 2001, 2002) imposed by the need for predictable navigation depths, stable shorelines and berthing areas, cost-effective methods for dredged materials management, transportation infrastructure and storage facilities, and for managing species adapted to human colonization (Swart et al. 2001).

Fig. 2. Views of modern Manhattan depict a human-dominated landscape where ecosystem baselines have permanently shifted, to the extent where opportunities for habitat restoration or rehabilitation are severely constrained by human uses and needs (photo provided by USEPA Region 2, New York).

This framework is easily captured by considering the Hudson River estuary beginning with the island of Manhattan (Fig. 1). An engineering survey of the island conducted by the King's Engineer in 1767 (U.K. Hydrographic Office, Somerset, U.K.; only the lower portion of the map is shown encompassing what was then New York City) depicted extensive wetlands numbering in the hundreds of hectares located mainly in the area of the World Trade Center complex, South Street Seaport, and United Nations area. Prime hunting grounds for indigenous wildlife and other game were available on the northern half of the island. A current view of lower Manhattan (Fig. 2) and surroundings connotes in dramatic fashion that natural baselines have permanently shifted and restoration goals for this estuary are necessarily conducted in a human-dominated landscape. As Weinstein and Reed (2005) have suggested, these goals are constrained by limited opportunities to conserve and preserve natural lands, restore biodiversity to historical baselines, and conserve species whose well-being is sensitive to human activities.

## Production Estuaries

Production estuaries are estuarine systems whose dominant eco-societal services are vested in sustainable harvest or culture of estuarine-dependent species. These estuaries support, or recently supported, extensive commercial and recreational fisheries, and/or aquaculture. Human population

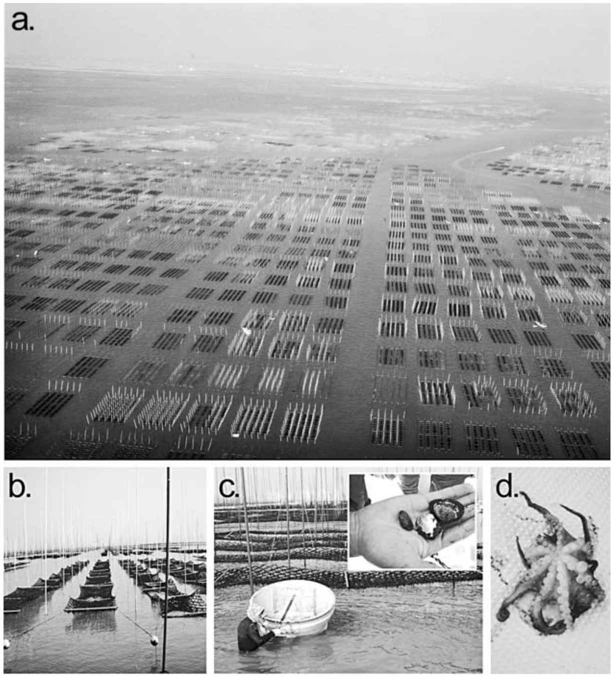


Fig. 3. (a) Ariake Sound, Japan, a semi-enclosed production estuary covering approximately 1700 $km^2$. Surface area of nori (*Porphyra* spp.) aquaculture coverage is expected to nearly double by the end of the century, from 20% to 40%. (b) A close-up of individual culture racks, Ariake Sound, Japan. (c) Shellfish harvest, Ariake Sound, Japan. (d). Octopus, *Octopus vulgaris*, part of a commercial-recreational fishery in Ariake Sound, Japan. (photo provided by Dr. T. Kusuda, Kyushu University, Fukuoka, Japan).

density is relatively moderate (Weinstein 2007). In such areas, priority is given to restoration/rehabilitation and fisheries optimization approaches that focus on habitat or other factors directly affecting the production of economically, and culturally important fish and shellfish. Ecosystem management would incorporate the use of artificial reefs, by-catch reduction methods, turtle excluder devices, and crop rotation techniques to allow the live bottom to recover from fishing gear effects. Other important societal uses include recreation, education, ecotourism, and landscape aesthetics.

A good example of a production estuary where aquaculture is a primary industry and centerpiece for sustainable management is Ariake Sound, Japan. Approximately 20% of the surface area of the estuary (1700 $km^2$) is presently in nori (*Porphyra* spp.) culture, a figure that will potentially double by the end of the century (Fig. 3). Farmers and other fishermen also harvest short-necked clam (*Ruditapes philippinarum*), jack-knife clam (*Sinonovacula constricta*), pen shell (*Atrina* sp.), and octopus (*Octopus vulgaris*) to supplement their incomes. Recent land reclamation and water diversion schemes in the inner Sound are thought to be a factor in the increased incidence of red tide and have negatively affected aquaculture and shell fisheries establishing new conflicts among sea farming and other human uses. Efforts are underway to rehabilitate these commercial grounds to their historic productivity.

## Conservation Estuaries

Conservation estuaries are largely undisturbed, self-sustaining systems with minimal human shoreline density and few, if any, human extractive uses. Nature and culture are largely separated, and natural processes and high levels of uncertainty dominate (Swart et al. 2001). Estuarine Reserves are an example of conservation estuaries in the United States. Generally small, they support nonconsumptive uses on a moderate scale, such as research, education, ecotourism, and provide aesthetic and cultural benefits to both local communities and society as a whole. In these areas priority is given to conservation and restoration focused on habitat quality and complexity that supports biodiversity and biotic integrity, including endangered or threatened species, migratory birds, and resident species of the estuary.

## Punctuations of a Continuum

Weinstein and Reed (2005) commented that the three estuarine types are simply punctuations of a continuum, and consciously made the borders between estuarine types appear diffuse rather than as sharp boundaries (see their Fig. 2). They also noted that individual estuaries might contain elements or significant areas of more than one estuarine type, and should be managed as such, perhaps by incorporating a zoning scheme in their management plans.

The Delaware Bay provides a good illustration; there are many others worldwide. Although, much of the fresh portion of the tidal estuary is occupied by two sizeable cities – Wilmington, Delaware, and Philadelphia, Pennsylvania – and their associated industry including petroleum distribution and ports commerce, the physiographic signature of these urban settings is minimally felt in the estuary proper. The saline portion of the Delaware Bay remains ringed by a nearly continuous tract of tidal wetlands that occupy more than 88% of the estuary shoreline. Moreover, $< 9\%$ of the total shoreline in the estuary is armored, and the population density in the coastal zone, about 1300 individuals $km^{-2}$, is only about 9% that of the New York metropolitan area (more than 14,500 individuals $km^{-2}$; Weinstein 2007). There are also striking differences in anthropogenic influences on subtidal lands in the Delaware estuary and New York-New Jersey Harbor,


Fig. 4. Conceptual scheme for identifying restoration ecology and ecological restoration goals and criteria for coastal restoration designs.

the density of dredged primary channels (not including tributary channels, canals, berthing areas, and turning basins) in New York-New Jersey Harbor is about nine times greater than in Delaware Bay (Weinstein 2007). Although not quantified, the extent of fill (to create fast land) in the Harbor is far more extensive than in lower Delaware Bay. To the extent that the lower Bay remains relatively undisturbed, Weinstein (2007) suggested that it could serve as a ''poster child'' for preserving a substantial portion of one of the nation's largest estuaries as an ecology managed area.

## The Application of Restoration Success Criteria

To balance human needs with that of extant biota, restoration practices should be comprised of consensus based combinations of restoration ecology and ecological restoration criteria (Fig. 4). Acceptable restoration designs will likely be a function of the estuarine type in question and the proportionate combinations of anthropocentric and ecocentric criteria prescribed by the vertical axis of Fig. 4. The goal is to devise plans that allow humans and other biota to share space and resources in an increasingly complex landscape (Pfadenhauer 2001). In Fig. 4, I have tried to emphasize that no matter where restoration takes place, both ecological fidelity (couched in ecocentric terms) and human dimensions (couched in anthropocentric terms) criteria should comprise the restoration design, but ultimately in proportion to human density in the landscape (Weinstein et al. 2007). Certainly, in urban-industrial settings restoration ecologists should embrace collaboration with the humanities and arts disciplines in the form of common research and implementation goals. So too is the need to involve the public and convince them of the necessity for science-based restoration; if people can identify with a given restoration approach as proposed by restoration ecologists, the outcome can be of critical importance to its implementation (Pfadenhauer 2001). Without this sort of integration and consensus, I fear that restoration will not prosper in the mainstream of society.

I also acknowledge the current debate on functionalist versus compositionalist approaches to ecosystem restoration and management (Woodley et al. 1993; Angermeier and Karr 1994; Callicott et al. 1999; Goldstein 1999), and suspect that we are simply dealing with punctuations of a continuum (Weinstein and Reed 2005). I use the terms ecosystem health and biological integrity to distinguish among the desired restoration end points in ecosystems that range from human dominated to those with minimal human intrusion. I adopt the term restoration for practices that attempt to return ecosystems to some optimum biological integrity (Angermeier and Karr 1994), whereas the term rehabilitation is used in human-dominated estuaries where the goal is to return degraded and altered portions of the system to renewed ecosystem health (Callicott et al. 1999). Restoration priorities in urban-industrial systems should focus on goals that favor both human and natural resource goals. From a purely practical standpoint, restoration ecologists sometimes agree that a complete return to the historical condition is very unlikely (Hobbs and Norton 1996). Especially in densely populated areas, multipurpose restoration is often more feasible than a purely scientific approach to restoration; e.g., by combining restoration goals with public access and recreation (Van Diggelen et al. 2001).

Adopting this approach also does not mean that ecosystem health is sacrificed; to the contrary, contaminant source control, suitable sediment and water quality, and the human endeavors to address them are just as important to sustaining commercial activity in urban-industrial settings as they are to the well-being of extant biota (Weinstein and Reed 2005). Concomitant goals in developing policy for management of urban-industrial estuaries are improved water and sediment quality, the conservation and preservation of existing critical habitat (''the proximate reservoirs of biodiversity''; Callicott et al. 1999, p. 32), and rehabilitation of other habitats that support species coadapted to the presence of humans (Swart et al. 2001).

Although the scientific documentation is scanty, some species appear to sustain their populations in human-dominated systems, unlike others that have suffered the effects of habitat loss and alteration, and water quality perturbations. These species might receive priority in restoration designs in urban-industrial estuaries. Anthropocentric criteria might also include access to the waterfront and outdoor recreation, cultural and maritime heritage activities, aesthetics, recreational fishing, wildlife observations, and other human goods and services provided to the local community or society as a whole.

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