FIGURE 2. The Ballona Wetland at sunset, looking southwest over the salt pan of Area B. PHOTO: COURTESY OF THE BAY FOUNDATION

ACHIEVABLE RESTORATION TARGETS FOR URBAN WETLANDS

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Abstract

Many of the earth's most altered ecosystems are urban wetlands, owing to their positions low in their watersheds. The most highly altered urban wetlands occur downstream from large developed areas with extensive hardscaping (impervious streets, roofs, driveways, and sidewalks). Compared to historical conditions, watersheds with substantial hardscaping discharge water in larger pulses of greater velocity than historically, and the water carries more contaminants. Moreover, since hydrological conditions are critical to the type and composition of wetlands, all downstream ecosystem components will be altered, creating novel hydroperiods and geomorphology, novel soils, and assemblages of plants and animals that are without analogs in natural ecosystems. Such is the case for the Ballona Wetlands (Fig. 1), whose hydrological conditions are highly modified and whose biota include native and nonnative species in new combinations.

FIG. 1. Aerial photo of the Ballona Wetland. This "diamond in the rough" is dissected by a flood control channel, bounded on the north by Marina del Rey and encroached upon by urban Los Angeles. Potential for restoration to make it "shine" involves minor to major interventions to increase the influence of ocean tides. PHOTO: COURTESY OF THE BAY FOUNDATION

Can restorationists turn back the clock? Not entirely (Seastedt et al. 2008). It is unrealistic to imagine that restoration activities could eliminate—or even compensate for—the many environmental stressors in urban wetlands or that restorationists could replace the full complement of species that once inhabited such ecosystems. At the other extreme, it seems unwise to allow environmental impacts to continue to degrade highly valued places such as the Ballona Wetland. Rather than pursing futile efforts to turn back the clock, restorationists could choose to acknowledge the many irreversible attributes of humanized watersheds and adapt restoration targets to landscape change. Here, I consider landscape change to encompass a broad spectrum of human effects—some direct, such as hardscaping, and some indirect, such as climate change.

An early book promoting urban wetland restoration in New Jersey suggests a similar approach. Casagrande (1997, page 254) stated that "Wetland restoration in urban areas is, in effect, restoration of human habitat." This acknowledges the role of people in setting restoration targets and the need to accommodate the human needs, for example, for education, recreation, and esthetic appreciation. However, he was not envisioning an amusement or water park, nor was he advocating endless efforts toward some historical ideal. Rather, he suggested dual goals such that "Urban wetland restoration can restore the ecosystem to a condition that maximizes human benefits while minimizing inputs of energy." He proceeded to advise readers on how to achieve that ambitious outcome: "By restoring ecological processes suited to the climate, topography, geology, and hydrological context of the restoration site." His next sentence was ahead of its time: "Such restoration does not require exact duplication of an historic landscape." In the process of "landscape-change adaption," restorationists can aim to achieve selected ecosystem services, including biodiversity support (Table 1), but they cannot expect to duplicate historical conditions.

TYPE OF SERVICES (MEA 2005)	EXAMPLES
Cultural Services	Esthetics: Breaks in urban landscapes Inspiration: Positive feelings, imagery for art Recreation: Birds to watch, trails to hike Education, research opportunities
Supporting Services	Supporting biodiversity Produce "food" for wildlife, microbes
Regulatory Services	Improving water quality Abating flooding Storing carbon
Provisioning Services	Producing fibers for crafts Growing plants that sustain gene pool

TABLE 1. Wetland ecosystem services (functions valued by people) that might be conserved, restored and sustained in the Ballona Wetlands. The four types of services follow the terminology of the Millennium Ecosystem Assessment (MEA 2005).

There is little virtue in insisting on setting targets that cannot be reached. It makes sense, however, to work to conserve and restore ecosystem services provided by urban wetlands. An earlier paper discussed the tradeoff inherent in urban wetland restoration (Callaway and Zedler 2004). On the positive side, the opportunities are greater, both for improving lands and for benefiting people. At the same time, the challenges are greater and the outcomes less certain because of the many interacting environmental factors and the uncertainties of human behavior (Table 2).

Three salt marsh restoration projects in San Diego County, California, illustrate several reasons to restore and sustain biodiversity, even if all species cannot be recovered:

1. Famosa Slough (37 ac) is just south of San Diego's Mission Bay Aquatic Park (http://www.famosaslough.org/map.htm). This wetland is hardly a duplicate of its condition in the early 1900s, when it was an extension of Mission Marsh downstream from a freely flowing San Diego River. Yet the urbanized Famosa Slough still serves local residents and visitors. After years of citizen efforts, the City of San Diego purchased Famosa Slough and then removed trees and homeless camps, treated inflowing runoff, and recontoured landfills. Meanwhile, volunteers created trails, removed exotic weeds, planted native species, and encouraged interpretive signage. The highly modified site attracts diverse birds, provides opportunities for wildlife appreciation and photography, and improves the quality of urban runoff.

2. Sweetwater Marsh on the east side of San Diego Bay is trapped behind acres of dredge spoil deposits. It is part of a National Wildlife Refuge, supports four endangered species and attracts local outreach programs for schools and the public (USFWS 2006). Citizens were instrumental in getting federal agencies to mitigate damages caused by freeway and flood-control construction projects. Some of the dredge spoil was excavated to create tidal channels and salt marsh; other fill was removed to create salt marsh islands. Moreover, two native plants —salt marsh bird's beak (*Cordylanthus maritimus* ssp. *maritimus*) and Pacific cordgrass (*Spartina foliosa*)—were planted to recover endangered populations: to provide nesting habitat for the endangered light-footed clapper rail (*Rallus longirostris levipes*). A visitor center on Gunpowder Point attracts school groups and the public.

3. Tijuana Estuary is downstream from a 1750-square-mile watershed that is mostly within Mexico, where slopes are greatly modified and soils are highly erodible. Tons of sediment moved downstream into the salt marsh with flooding during the stormy phase of the Pacific Decadal Oscillation (1978 to present). However, the estuary still supports many sensitive plants and animals, of which three are on the federal list of endangered species. These are the California least tern (Sterna antillarum browni), light-footed clapper rail, and salt marsh bird's beak. Also abundant at Tijuana Estuary is the state-endangered Belding's Savannah sparrow (Passerculus

+	More people will be served
	Recreation for bird and plant watchers Esthetic enjoyment by artists, photographers Stress reduction related to open space
-	More wastes need to be processed
	Nutrients from lawns and runoff Contaminants from streets Carbon dioxide from people, vehicles, and engines
-	Habitats are more isolated
	Insufficient dispersal Disturbed edges Lower diversity of species, genotypes
-	Exotic species will likely invade
	Human dispersal Excess runoff, lowered salinity Disturbance
-	Altered hydrologic and sediment dynamic
	More fresh surface water inflow Less fresh groundwater discharge due to groundwater pumping Poor water circulation due to roads, berms More sediment inflows due to construction upstream
-	Loss of transition from marsh to upland due to urban fill and steep banks
	Loss of high-tide refuges for mobile species, such as clapper rails Loss of bee habitat and reduced pollination of rare annual plants Loss of sensitive transition species such as box thorn (Lycium californicum) Loss of box thorn services, such as bird perching and nesting, small mammal cover and runways; natural "fences" provided by its spines and dense canopy (James and Zedler 2000).

TABLE 2. A major benefit (+) and many constraints (-) involved in restoring urban wetlands, relative to rural wetlands with less-altered watersheds (from Callaway and Zedler 2004).

sandwichensis beldingi). This site has multiple designations: National Estuarine Research Reserve, Ramsar Wetland of International Importance, State Park, and County Park. It attracts visitors and supports research and education for all ages.

When I moved to Southern California in 1969, all three of the above coastal wetlands were more degraded and more threatened by neglect and misuse than they are today. A few key citizen leaders and many who followed their leads transformed each of these "diamonds in the rough" into cultural and ecological amenities. Jim and Barbara Peugh led (and still lead) efforts at Famosa Slough; Joan Jackson was a key player in augmenting mitigation efforts at Sweetwater Marsh, and Mike and Patricia McCoy were critical in keeping Tijuana Estuary from becoming a marina. In every case, local residents helped to persuade public agencies to work toward restoration, and they sought science-based approaches to conserve and restore wetland biodiversity and related ecosystem services (before that term was in use).

The Ballona Wetland is also a diamond in the rough; it has many values in its present degraded condition and it has the potential to "shine," that is, achieve realistic restoration targets. How might it be restored to a "condition that maximizes human benefits while minimizing inputs of energy…by restoring ecological processes suited to the climate, topography, geology, and hydrological context," as Casagrande (1997) suggested? How can it be sustainable into a novel future, given all the constraints of an urban wetland (Table 2)? Once we acknowledge that we cannot turn back the clock, either for the watershed or the site, we can focus on accommodating landscape changes, even though we cannot predict details of future environmental conditions, including human behavior.

To meet the challenge of setting goals for an unknown future, I recommend establishing an adaptive restoration process that allows restorationists to distinguish achievable and unachievable targets based on field experimentation (Zedler and Callaway 2003; Zedler 2005). Adaptive restoration begins by establishing a restoration task force that is empowered to plan and implement restoration using field experimentation and related monitoring. The process is iterative and long term; it is based on obtaining data through long-term monitoring of both the site as a whole and experimental plots, interpreting the results, communicating the findings to a broad range of stakeholders, distinguishing achievable and unachievable targets, and adjusting targets accordingly. In planning experiments, it is important to aim high, that is, to set potential targets that might be achievable, then establish long-term field experiments to test alternative actions (Table 3).

Scenic views and photogenic species provide cultural services at the Ballona Wetland (Table 1), although there will always be some disagreement about which attributes are beautiful and which are impaired. Both the positive and negative descriptors (beauty, impaired) involve subjective judgments, and it is unlikely that all of the people will be pleased all of the time and in all places. I suggest that stakeholders agree on some basics, however, to the effect that native species are preferable to non-natives, and regionally rare species could be promoted for establishment even if there is no historical record of their occurrence at Ballona Wetlands. Examples are Pacific cordgrass, salt marsh bird's beak, box thorn (*Lycium californicum*), and tidewater goby (*Eucyclogobius newberryi*).

It is difficult to specify the ecosystem services that are restorable, and there might be disagreement about the services that should be restored first. Still, the public should know about the high value of ecosystem services that wetlands provide, despite their small global area. According to Costanza et al. (1997), tidal marshes provide services worth $9,990/ha/yr, mostly for "waste treatment," and estuaries provide services worth $22,832/ha/yr, mostly for nutrient cycling (Costanza et al. 1997). Of the many wetland services, N removal is especially valuable (Jordan et al. 2011).

EXAMPLES OF POTENTIAL TARGETS	POTENTIAL EXPERIMENTS WOULD TEST:
Establish some of the region's valued species (bird's beak? cordgrass? box thorn? tidewater goby?)	Alternative methods for introducing each species Alternative places and times to introduce each species
Detoxify soil contaminants	Alternative soil amendments Alternative plantings
Jumpstart creek formation	Ability of creating small vs. large channel mouths to catalyze creeks to form dendritic systems
Test the ability of habitat/ nesting islands to enhance native bird populations	Islands of varied size and shape, if intertidal areas are suitable for a large experiment

TABLE 3. Some potential targets for the Ballona Wetland and ways to test if and how they can be achieved.

Restoring downstream urban wetlands is challenging, partly because of current landscape changes and partly because we have to anticipate unknown future conditions. We can rarely be certain which targets are achievable. However, adaptive restoration can distinguish the unachievable and achievable targets, and at the same time, identify the more effective methods for progressing toward project goals (Table 4). For example, if diverse vegetation does not appear to be achievable, it might still be possible to create microsites that support species that might otherwise fail to establish. In one experiment at Tijuana Estuary, we flattened a tidal plain and unknowingly prevented it from sustaining annual pickleweed (*Salicornia bigelovii*). Years later, the persistence of this plant in shallow pools nearby suggested its chief competitor, the perennial pickleweed, has a strong advantage except in the more waterlogged soils. Subsequent experimentation indicated that the annual can be sustained where ~5 cm of tidal water is retained at low tide (Varty and Zedler 2008). Additional research would be helpful in determining where complete dominance by perennial pickleweed can be avoided and more diverse vegetation is achieved.

Diversity should be most readily achieved where multiple habitats are provided in close proximity. Bird's beak can grow in disturbed high intertidal marsh, but as an annual plant, it needs ground-nesting bees to pollinate its flowers so seeds can perpetuate it. Thus, it did not thrive when seeded to a small island that was fully submerged at high tide at Sweetwater Marsh, but did reestablish where supra-tidal ground was present nearby. In another example, clapper rails need low marsh for nesting, marsh plains for foraging, and high marsh and transitions to upland for high-tide refuges in midwinter. These birds, including eggs and chicks, are vulnerable to both terrestrial and aerial predators in all locations, so dense vegetation is needed in the wetland-upland transition (to avoid dogs, cats), as well as tall cordgrass in the low marsh (to be less visible to raptors).

It is difficult to restore rare and endangered species in Southern California, in part because there are few coastal wetlands that are fully tidal, and in part because habitats are smaller than they were historically. Adapting to landscape change in the restoration of rare species would thus require a shift from strictly adhering to historical sites to including other sites where their habitat can be restored. Because the exact conditions of each restoration site cannot be predicted or even measured in great detail, I suggest aiming for heterogeneous topography, to include areas of supra-tidal land, the full range of tidally influenced wetlands, and complex tidal creek networks. Even exaggerated excavations can be beneficial, as at Tijuana Estuary's Model Marsh, because some degree of erosion and sedimentation are certain to occur. The Model Marsh might owe its shallow tidal creek networks to the excavation of deep channels early on (Wallace et al. 2005). There is ample room for more geomorphological research. For example, a large field experiment could test the need to over-excavate creeks in the Ballona Wetland. Questions that are amenable to experimentation are: Which

WETLAND	TARGETS REACHED	TARGETS RULED OUT	REFERENCES
San Diego Bay: Sweetwater marsh	Least tern foraging habitat (channels with fish) Salt marsh bird's beak established from seed	Nesting habitat for light-footed clapper rails could not be sustained due to sandy dredge-spoil substrate that could not accumulate nitrogen	Zedler 1993, Langis et al. 1991, Boyer and Zedler 1999, Williams and Zedler 1999, Parsons and Zedler 1997
Tijuana Estuary: Tidal Linkage	Native salt marsh can be established on tidal plain	Diverse plantings are not sustainable where conditions allow strong dominance by pickleweed	Callaway et al. 2003, Zedler and West 2008, Doherty et al. 2011
Tijuana Estuary: Model Marsh	Annual pickleweed can establish and persist in shallow (5 cm) pools	Diverse salt marsh not sustainable with sedimentation	Varty and Zedler 2008
Tijuana Estuary: Model Marsh	Fish use tidal creeks as habitat and corridors to the marsh plain where they feed in tidal pools	Large, deep channels are not sustainable far inland from the ocean mouth where sedimentation exceeds erosion	Larkin et al. 2009, Wallace et al. 2005

TABLE 4. Examples of adaptive restoration. In each case, experiments ruled out unachievable targets and helped managers to accept achievable alternatives.

environmental damages are reversible? Which ecological targets are achievable? Which plant species are most easily established and most readily sustained and most functional? What role can islands play, and which island sizes, shapes, and edge:core ratios are most effective in providing ecosystem services, including biodiversity support? Where will irrigation be needed? Where might pollinators be limiting to annual plant populations?

In restoration, practitioners should not expect to achieve all aims. Restoring habitat for endangered species is tough, and restoring sustainable populations of endangered species is tougher. No effort that I have been involved in avoided surprises, and the surprises led to expectations such as the following: Weather can be helpful (rain after planting) or fatal (tides add seawater; drought during low tides can cause mortality). Sedimentation and erosion will occur (despite heroic efforts to trap sediments upstream or position excavation sites where they will not fill in). Nutrient-rich conditions can enhance cordgrass growth (at low levels) or cause annual pickleweed to outgrow it (with prolonged use of fertilizer; Boyer and Zedler 1999). Algal blooms can smother seedlings (direct effect) and attract coots that trample young plantings (indirect effect). We can use a variety of attributes to track restoration progress, but each can follow a unique trajectory (Zedler and Callaway 1999). Greater understanding comes from tracking multiple ecosystem responses. Returning to Casagrande (1997), I agree that "Wetland restoration in urban areas is, in effect, restoration of human habitat." The Ballona Wetland will always be a human habitat—it is a rare coastal open space in an urban landscape. I am uncertain about the claim that "Urban wetland restoration can restore the ecosystem to a condition that maximizes human benefits while minimizing inputs of energy." It is not clear how we can both maximize human benefits and minimize inputs of energy in the Ballona Wetland. Many of the restorable services are cultural and valued differently by those who appreciate the Ballona Wetland as is and those who see a more fully tidal future—in one of the last places where such a transformation is possible. Scientists can advise on how and why to sustain one or the other, but only the stakeholders can decide whether or not to fight for one or the other scenario or to work toward a compromise. I agree that we should proceed "by restoring ecological processes suited to the climate, topography, geology, and hydrological context of the restoration site." The site is suited for restoration to a fully tidal estuary. The initial investment will be large, but so will the rewards, especially if biodiversity and services become sustainable with minimal energy input. I agree that "such restoration does not require exact duplication of an historic landscape." Even if we could duplicate historical conditions, not all would agree on a time period or specific state to mimic. Ecosystems are too dynamic to specify exact outcomes or to expect any state achieved in the short term to be sustained into a novel future.

Today's urban wetlands are diamonds in the rough that can become tomorrow's shining jewels (Fig. 2). We all need to work together to make Ballona Wetlands and other Southern California wetlands shine—brilliantly!

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