biomass, and height, most of these sites are progressively developing attributes comparable to adjacent, albeit disturbed, reference sites (CORDELL *et al.,* 2001). Even in heavily industrialized estuaries, vegetation can be a robust metric of restoration performance. However, given the potential injury and damage to aquatic resources in the Duwamish River estuary, monitoring of fish and wildlife response is important. Restoration in urban estuaries such as the Duwamish may need to address a somewhat higher order: If you build it, will they come and not suffer for it? Due to the emphasis on CERCLA injury compensation and Endangered Species Act (ESA) contribution to salmon recovery, particular attention has been focused on monitoring responses to restoration sites by juvenile salmon, their prey resources, and other habitat attributes. This can be particularly difficult when the particular attributes that link juvenile salmon habitat to their fitness and survival are unknown or purely inferential and appropriate reference conditions are lacking (SIMENSTAD and CORDELL, 2000). COrdell *et al.* (2001) document the dilemmas in trying to assess ecological function of restoration sites in the Duwamish River estuary, especially juvenile salmon habitat. Their approach has been to examine indicators of the capacity of the restoring habitats to support salmon (*e.g.,* abundance and distribution of potential prey organisms) and to identify the attributes (*e.g.,* vegetation, substrate) that account for that support, relative to the few relict patches of natural shoreline in the estuary (Figure 3). They noted that, in general, prey of juvenile salmon in the Duwamish River estuary is dominated more by a composition of insects (*e.g.,* collembolans, psyllids, ants, wasps) different from what is commonly documented in the diet of juvenile salmon (chironomid larvae, pupae, and emergent adults) in natural and restored habitats in other estuaries in the region. However, prey composition from fish occupying the T-105 restoration site was generally parallel with those captured at the nearby reference site (Kellogg Island), suggesting that this difference is occurring at the estuarine landscape scale and not at the site or habitat scale. CORDELL *et al.,* (2001) suggest that this effect may be attributable to the limited distribution of emergent vegetation in the estuary.

Monitoring of juvenile salmon prey resources provides another, perhaps more direct assessment of the performance of a restoring site (SIMENSTAD and CORDELL, 2000). Sampling for benthic infauna or insects indicated that the juvenile salmon prey taxa *Corophium* spp. amphipods and the larvae of ceratopogonid flies were equally or more dense at some restoration sites adjacent to reference sites, and comparatively more abundant than comparable natural habitats in the considerably less-disturbed, rural estuary of the Snohomish River (CORDELL *et al.,* 2001). Thus, although the diet of juvenile salmon migrating through the Duwamish River estuary includes prey that are not typical of less-altered estuaries, they are utilizing the types of organisms that colonize restoration sites. Other functions, such as refuge from predation provided for juvenile salmon by shallow-water habitat may be provided as soon as the restoration site is developed, although there has been no monitoring or studies to validate that decreased predation rates occur in restoration sites.

DISCUSSION

Restoration in the Duwamish River estuary has been driven by a number of regulatory/legal mandates and obligations above and beyond the fundamental desire to return portions of the system to some resemblance of its original function. Mitigation under the Clean Water Act, damage compensation and rehabilitation under CERCLA, and salmon habitat restoration under ESA all have provided impetus for the restoration actions completed to date. In addition to these mandates, native American treaty rights guaranteeing harvestable salmon and joint involvement in salmon management adds additional incentives and resources for aquatic habitat restoration in the estuary. Management of trust resources demand restoration as part of compensation. The fact that the Duwamish River estuary has the largest concentration of estuarine restoration sites in the Pacific Northwest region of the USA is unquestionably due to these regulatory mandates.

It might be argued that the impetus for restoration would not have reached the threshold that prompted non-regulatory actions if these regulatory actions had not occurred. Certainly, the ultimate performance of critical functions, such as providing habitat for recovering salmon stocks, will ultimately depend on the successful CERCLA remediation of toxic contamination, because this regulatory action will determine whether or not risks to juvenile salmon caused by recontamination of restored sites outweighs the benefits of the created habitat.

As in almost all restoration programs in urban, industrialized estuaries, sites and designs in the Duwamish River estuary are generally opportunistic. They are largely driven by the availability, location, cost, and other constraints of limited restoration sites. By design (KCDMS, 1994), the diverse restoration actions in the Duwamish River estuary over the past decade have in aggregate formed a landscape approach consisting of clusters of sites in strategic locations along the estuarine gradient that are perceived to be critical for migrating juvenile salmon. This "strategy" may not be as beneficial for other resources or functions, but likely serves the most prominent goal of restoration—salmon recovery—in this estuary. Some landscape connectivity in the system has also emerged, intentional or not. Cumulative restoration projects may provide habitat linkages that will create a landscape-scale habitat function for migrating salmon that exceeds site-specific levels. The linkages of Hamm and Puget Creeks to upland drainages provide peripheral freshwater input, drift organisms, detritus, and fish and wildlife corridors to park green spaces; in the case of Hamm Creek, salmon spawning habitat is connected to the estuarine restoration. Present urban runoff and stormwater management continues to constitute a potentially non-trivial source of contaminants from the large area of surrounding impervious surfaces. Obviously, one of the greater challenges to urban estuarine restoration is control of toxic contamination sources.

Other urban estuary factors, such as the impacts on planted and naturally recruiting vegetation by Canada goose grazing, constrain the natural development of estuarine emergent vegetation assemblages. However, research on the scale of this disturbance factor suggests that certain restoration design and management strategies can mitigate for this factor. To establish persistent marsh vegetation on restoration sites in the Duwamish, CRANDELL (2001) recommended the following practices:

1) Physically protect *C. lyngbyei* shoots in areas frequented by Canada goose to prevent total loss of plant material. Three-foot-high fencing should surround a planted area, with nylon (or other) line crisscrossing the top of the protected area.
2) Protect plants for at least three years and as many as five to prevent irreversible degradation following eventual exposure to grazing. The minimum size of a planted stand might be 30 m^2 in areas experiencing 330–450 goose-days ha^{-1} of available *C. lyngbyei*.
3) Install exclosures in native established stands of *C. lyngbyei* that are currently grazed by geese in order to provide a boost to the BG development and long-term fitness of the stands.
4) Plant *C. lyngbyei* in conditions for which it is well suited so that it can compete successfully with volunteering plant species that may also be able to grow once grazing pressure is removed.
5) Install exclosures in unvegetated areas at elevations that might be expected to support bona fide intertidal vegetation so that volunteering species can become established.

Perhaps one of the most significant functions of urban estuarine restoration observed in the Duwamish River estuary is not ecological or geochemical, but social: citizen support, investment, and direct involvement in estuarine restoration has flourished with the recognition by citizens that some degree of rehabilitation of damaged ecosystems in their "own backyard" is feasible, and that they can take some responsibility for it. Urban revitalization focused in derelict industrial areas would generate more estuarine backyards and, presumably, more incentive for restoration of a sustainable city environment. Such direct contact and involvement with urban restoration has many cultural benefits because it addresses the historical, social, political, aesthetic, and moral attributes, as well as the technical goals, of restoration. And, while restoration in rural and isolated estuarine settings may be self-sustaining, restoration in urban estuaries will not be sustainable without public commitment to long-term stewardship, well after entities such as the CERCLA trustee panel have dissolved.

The investment is large and the risk commensurate. However, small incremental improvements in such degraded landscapes may have disproportionately large impacts. Strategic restoration actions have the potential to produce a huge signal: noise response. As seen in the Duwamish River estuary, despite the small incremental steps taken, habitat area and quality has expanded from a minute and continually degrading base prior to the 1970s to a progressively broader distribution of rehabilitated patches clustered in ecologically meaningful regions of the estuary.

Evidence of the benefit to fish and wildlife from habitat restoration is still somewhat ambiguous.

It is uncertain whether or not growth and survival is increased due to their increased use of restoring habitats in the estuary. However, in the case of some resources, such as at-risk anadromous salmon, we must ensure that restoration and all other measures toward salmon recovery based in the watersheds are matched by equal efforts to rehabilitate salmon habitat in estuaries. By monitoring and study of key metrics linking the attributes of restoring sites to their function for aquatic resources such as juvenile salmon, we have isolated some relationships that may direct the increased scaling up of restoration approaches and locations. For instance, the association of preferred prey with emergent and riparian vegetation (CORDELL *et al.,* 2001) provides information for more strategic designs for future restoration.

CONCLUSIONS

In retrospect, any enthusiasm for the potential of restoration in urban, industrialized estuaries must confront the reality that "this is not your average restoration." In areas such as the industrialized Duwamish River estuary, true restoration is not possible; rather, it is expensive rehabilitation and enhancement at best. Exemplifying what WEINSTEIN and REED (*in press*) consider an *urban-industrial* estuary, the Duwamish provides the challenge of ecosystem rehabilitation in a landscape dominated by industrial development. Because of these obstacles it is easy to discount the potential return on the investment, however large and long-term. Urban estuarine restoration demands different approaches that address, and perhaps even take advantage of, the urban landscape:

- Acknowledge system constraints and understand and work with existing natural processes. Probably the biggest misconception is that urban/industrialized estuaries can be returned to predevelopment conditions. Understanding anthropogenic changes in key ecological processes, and how they limit the approaches, patterns, and rates of restoration, is essential to realizing the spectrum of possible responses. As with the fundamental understanding of any estuary, this requires knowledge of key processes that originate from the watershed and receiving coastal waters, as well as from within the estuary.
- Learn from what is already in place. Consider the experimental tableaux of the urban estuary as a testbed for landscape concepts, alternative restoration approaches, performance metrics, and monitoring in challenging systems. Understand how to use the landscape connectivity and other conservation biology concepts of landscape ecology, both proximally and at regional scale, as a way to maximize the constrained array of restoration options available. This includes the larger-scale contribution of the estuary to coastal receiving waters such as Puget Sound in the case of the Duwamish River estuary.
- Explore innovative and adaptive approaches. Treat restoration projects as adaptive management experiments and *intensively* monitor and experiment. In the best of cases, even in relatively undisturbed ecosystems, estuarine restoration is experimental. In the case of urbanized/industrialized estuaries such as the Duwamish, we cannot afford not to formalize adaptive management and adhere to its most rigorous concepts.
- Realize that the characteristics of placing relatively small restoration sites in a larger matrix of urban environments requires significant and ongoing stewardship, but also that human resources and institutions are available and ready to help.
- Expand social and cultural connections and institutional commitments. Ultimately, whether or not investment in restoration of urban estuaries will become accepted will depend upon public realization that the return on the investment is worthwhile.

If we can continue to document how and why estuarine ecosystem functions can persist in the face of sustained economic, social, and cultural pressures, we have the potential to change perceptions about whether or not it is worthwhile investing in restoring urbanized/industrialized estuaries. This requires a mechanistic understanding, demanding much more than a "build it and they will come" confidence in mimicking structural elements of estuarine shorelines, wetlands, and channels. It requires understanding, most importantly, the legacies and futures of the human imprint, but also the surrounding landscape and which ecosystem processes can persist and be recovered at the watershed scale. Ultimately, it requires realization that ecologically functioning estuaries are a social, economic, and cultural investment.

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