Living Shorelines

The Science and Management of Nature-Based Coastal Protection

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Foreword

It is likely that only the few who have never been exposed to the shores of oceans or large lakes are unfamiliar with the human struggle to supplant nature's dominance over shoreline stability. The so-called hardening of shorelines is a historic and pervasive alteration of coastal environments to counteract change, understandably to counter the devastative effects of major storms and sea level rise but occasionally simply for cosmetic purposes (Charlier et al. 2005; Nordstrom 2000). It has virtually been incorporated into the DNA of those who have occupied or managed shorelines since the first human millennium. Consider the persistent remnants of the seawall still standing on the shores of Batroun Bay, Lebanon, built by the Phoenicians in ca. 1st century BC, or the oak castrum seawall-equivalent that protected the 10th-century St. Donatian's church in Bruges, Belgium, in an era when the medieval town once fronted the sea and Vikings rode the waves. The long history of human desire to dominate nature is now manifest in vast coastal infrastructures of sea walls, groins, revetments, gabions, breakwaters, and other static engineered structures for coastal protection.

This irony is, of course, that the ecosystem goods and services provided by natural shorelines are the consequence of their naturally dynamic character. What we increasingly recognize as the functions and values of erodible shorelines more often than not depend on energetic erosion and accretion processes that maintain a dynamic equilibrium, but not necessarily a spatially static landform. As Dean (1999) observed, "Shoreline hardening to thwart nature's ebb and flow is therefore the antithesis of beach conservation."

Increasing recognition of the physical–ecological processes that account for resilient, sustainable shorelines has necessitated reassessment of the static shoreline model. With accelerated sea level rise, as well as cumulative development along coasts, we have begun to recognize coastal zones as linked social–ecological systems, where human effects and natural processes complicate system dynamics (Kittinger and Ayers 2010). However, reinstituting natural ecosystem processes to promote a full suite of natural ecosystem goods and services is generally unfeasible under all but the most reversible conditions. While "ecohydrology" and other physicochemical principles can be employed to shift shoreline ecosystems more toward their remaining natural potential, "ecoengineering" approaches are often necessary to adapt to the persistent effects of shoreline degradation, climate change, and socioeconomic and societal constraints that limit or target delivery of specific goods and services, such as public safety (Elliott et al. 2016). The result is more often than not a "novel" ecosystem state, where rehabilitation or reallocation are the only options to restoration (Aronson and Le Floc'h 1996; Bullock et al. 2011; Hobbs et al. 2013). While not restoration *per se*, such "hybrid" nature-based approaches to living shorelines may be intended or even designed to provide shoreline protection and ecological function as a "win–win" for both society and ecology, albeit with acknowledged trade-offs (Elliott et al. 2016; Rosenzweig 2003).

This volume is likely the first consolidation of the science and application of living shorelines that encapsulates diffuse approaches to and lessons learned from such "win–win" ecoengineering. Although the authors' context of living shorelines is broad—constrained only by the degree to which the connection between aquatic and terrestrial habitats is maintained and engineered structures dominate—they capture the common purpose of protecting shorelines and infrastructure as well as conserving, creating, or restoring natural shoreline functions in estuarine, marine, and aquatic systems (Bilkovic et al., Chapter 1). That the impetus to pursue living shorelines is accelerating, perhaps commensurate with coastal squeeze, argues for synthetic critique of available nature-based tools, documented ecosystem goods and services, social or economic metrics, legal and policy considerations, and approaches to community engagement that this volume offers. The regions, ecosystems, scales, and perspectives represented across the 24 chapters capture much of the variability in approaches to and results from living shorelines around the world. Various "beach to reach" scale investigations are represented from estuaries around North America, particularly from Chesapeake

Bay, the Louisiana–Mississippi Gulf of Mexico, and Australia, to broader, programmatic-scale examples provided from the Netherlands, United Kingdom, and France. Diverse ecosystems are also well represented, from confined estuaries to estuarine complexes, such as Chesapeake Bay, San Francisco Bay, and Puget Sound, to coastal shorelines of Europe. As imagined from the plethora of approaches to shoreline armoring, the applications are as divergent, from removal/modification of coastal levees and other extensively engineered features of open shores to seawalls of urban and port settings. Perhaps most attractive to the manager and practitioners of living shorelines, the perspectives span the spectrum of factors they will need to evaluate, including social and regulatory considerations they will need to build a supporting constituency, to detailed scientific and technical information that will be required to justify and design living shoreline projects. Perhaps the intrinsic value available in these chapters, and particularly in Davis' Chapter 23 on knowledge gaps, may be the lessons learned that authors have sought to synthesize and extrapolate into what is required in moving forward to advance the state of knowledge. In many respects, a thorough reading of this volume should provide the essential experience for adaptive learning to the next era of shoreline armoring. This is particularly the case for many of the examples and recommendations for metrics to assess the need (e.g., wave power, Chapter 11), structural effectiveness (e.g., structure–current interactions, Chapter 12), or ecosystem goods and services responses (e.g., faunal biodiversity and populations, Chapters 17, 19, 20, and 22) of alternative living shorelines.

Perhaps one of the most notable sources of living shorelines rationale represented in these chapters are clear measures of ecosystem goods and services that can derive from living shorelines elements. Diminution of wave and tidal surge effects on shoreline erosion are the most intuitive, especially as presented as guidance based on technical information on responses of tidal marshes to wave power (e.g., Chapters 11 and 13). However, nutrient reduction (e.g., Chapter 14) and particularly fauna colonization and diversity (e.g., Chapters 15, 17, 19, 20, 21, and 22) substantiate the potential contributions of different living shoreline approaches. Strayer and Findlay (Chapter 16) measurably advance this assessment further by providing an analysis across metrics of ecosystem structure (biodiversity), functions (decomposition), and services (recreation).

As with any multifaceted volume of this breadth, where most contributions are reviews of very different perspectives on living shorelines in specific regions and ecosystems, the level of detail and generality vary. Accordingly, the reader should recognize that much of the real value is the background cited studies that the authors draw on and relate to. Note that there remain considerable uncertainties about the approach and benefit of living shorelines recognized both implicitly and explicitly in these chapters, and most comprehensively by Davis in Chapter 23. For instance, it is still a struggle to find in this volume and the supporting literature examples of rigorously scientific (e.g., BACI, randomized control) comparisons of the ecosystem outputs, goods, services, or functions among typically armored shorelines, completely natural shorelines, and living shoreline constructs that are propositioned as alternatives (see Gap #9, Chapter 23). Similarly, quite often the application of idealized living shoreline features, particularly oyster reefs and seagrasses, to the construction of living shoreline projects for shoreline protection is not explicitly transferable (e.g., often the findings are from regions of estuaries and coasts not particularly vulnerable to shoreline erosion). An analysis that may have to be addressed in the next iteration of this volume is the cumulative and interactive effects of living shoreline elements, as it seems this approach or issue has yet to be addressed opportunistically or experimentally.

If there is any perspective that still dominates living shorelines, it is that "natural elements" are broadly recognized as the primary tool of living shorelines. Except for the large, coastal-scale approaches (e.g., managed realignment), ecosystem process-based approaches are less often considered as viable alternatives, either in socioeconomic analyses of trade-offs or in presenting long-term prognoses of shoreline change with stakeholders. For a vast array of shoreline protection scenarios, novel ecosystems are the only feasible outcome of such hybrid approaches that involve implanting specific features, either for the purpose of enhanced biodiversity and ecological function or

for specific ecosystem goods and services. Enhancing the ecological and other functions in socio-economically constrained settings such as seawalls is a given win–win. However, in the predicted future of rising seas and intensifying climate events, the sustainability of living shorelines will need to be assessed much more meticulously with nature-based approaches scaled from the long-term synthetic plans to incremental, site-specific solutions that take advantage of natural processes rather than just unmaintainable features. This volume provides critical insights into the science and technical, sociocultural, and practical factors that will ultimately be required for decisions about how to move in that direction.

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