Chapter 8
Beyond Restoration: Planting Coastal Infrastructure

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Abstract The following research project proposes a model whereby the biological arrangement of plants in space and over time can lead to a new paradigm using the modification of coastal ecologies, to move beyond restoration, ultimately dissolving the limiting dichotomy between green and grey infrastructure.

Keywords Resilience · Green infrastructure · Ecology · Botany · Coastal landscape · Planning · Design

The future of coastal resilience may rest on the adaptive capacities and changing dynamics of plants. Yet plant matter rarely serves as the basis of resilient strategies. In place of vain notions of permanence, the following model of coastal living for this century begins with plants and ultimately challenges the defining characteristics of restoration and green infrastructure. The plant is used as a scalar device, amassing relationships and providing the foundation for a portfolio of interventions. Plant life enables new programmatic incentives, increased terrestrial resources, and flexible attenuation measures, without resorting to restrictive or outmoded procedures associated with reconstruction. Once acknowledged for its contribution to shaping coastlines, the plant establishes a prominent position within the ecological sequence, an adaptive model for an uncertain future. Such a proposition also necessitates a reexamination of the word resilience, as its application has been recently mainstreamed following major storm events. In particular, this project proposes that plant dynamics are the raw matter of any valid model of resilience, suggesting that the trajectory of resilience planning as a metric of defense may be quite different than the one that is currently being imagined.

The ideas offered as part of this research synthesize around the necessity for new paradigms in practice, in order to move away from the commonly held idea that the materials of grey infrastructure (concrete, steel) are resilient to storm events and that

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the role of green infrastructure is not one of protection or defense, but of ecosystem services. By offering a consideration of plants in which woody material becomes the primary wave attenuating agent, the proposal exploits disturbance regimes to cultivate rhizomes, plant species with extended and interconnected root mass, as structural components. The influence of the root zone can be measured alongside other built features, yet has the capacity to adapt uniquely over time. Faced with uncertainty as a result of a changing climate, self-organizing processes can be harnessed to generate ecological transitions and alternative scenarios that do not replicate a past equilibrium or offer a false promise of stability. The project is therefore both a construction detail and a methodology that studies not just the isolated behavior of certain plants and their ability to sprout back, but also their contribution to the entire ecological fabric of a shifting coastal, marine, and estuarine landscape. Accepting the ongoing transitions of plant life as a design feature releases the anxiety that surrounds restorative safeguarding and changes the course of resilient measures.

The Urbanized Coast

Resilient strategies often find themselves in a deeply contradictory position when determining the balance between security and vulnerability during stress periods. When applied to coastal development along the North Atlantic, the suggestion of resilience cannot overcome the reality of an extremely susceptible and exposed built condition (Fig. 8.1. The Urbanized Coast). Development is typically centered on the affluent coastline; the thin threshold between land and water where the impacts of sea-level rise are most severe and the possibility of retreat, buyouts, and relocation mobilize policy (Adger et al. 2011). Retreat does not align with contemporary practices that prioritize the capacity to build back and unite around a return to life as usual. Retreat tends to signify defeat. As a result, event-based reconstruction has emphasized rebuilding armored structures, largely by increasing elevation and installing berms, albeit with a growing emphasis on ‘natural systems’ that seemingly indicate more flexible typologies in the face of indeterminate conditions. Termed ‘green infrastructure’ projects rely heavily on status quo standards of valuation based engineering, reasserting the enduring distinction between artificial and natural systems. Most green infrastructure is either a conservative restoration project or green veil obscuring a grey infrastructure project—a vegetal embellishment draped across a higher seawall elevation. The grey performs, the green distracts, and together they are called resilient. Following the devastation of superstorm Sandy, resilience has also come to define the repair and reconstruction of such features that are none the less called natural; the restoration of swales, dunes, wetlands and marshes that are expected to offer a more nuanced and adaptable type of coastal security.

The terms restoration and resilience have evolved over the past decade to describe both the diagnosis and the cure of climate based coastal management

Fig. 8.1 The North Atlantic can be read as a series of fortified shoreline conditions, constructed borders and armoring projects. The urbanized coastline disregards its oceanic position, securing its terrestrial claim instead. Tracing the influence of major events such as Hurricane Sandy reveal extended thresholds between land and water. *Credit* Ocean State project

practices. More precisely, they threaten to become codependent as resilience takes on greener intentions and the role of restoration is empowered by state and federal regulation (Hollnagel 2009). This combined authority has stymied more experimental approaches. A false sense of security surfaces within restored communities or adjacent reconstructed seawalls, expressed by the proposition of designing for stable and predictable outcomes. This tendency not only rehearses current practices but also limits the potency of future or alternative outcomes. The environmental narrative of decline services the nostalgic considerations of conservative environmentalism, and has become emblematic of current 'resilience' funding and resilient strategies (Bennett 2001). Yet the term holds great promise and as such, deserves to be problematized in order to become a catalyst for thinking about a very different model of resource management.

From Systems to Individuals

Plants emerge and 'spring back' based on regimes of disturbance. This attribute is a result of their fundamental competitiveness, a primary function of reproduction and development that warrants their use along the coastline, regardless of native or restorative ideologies. Ecology is composed of layers of interconnected and interrelated organisms; the animation of this ecology is driven by an individual species' ability to flourish. When new species appear within a former ecology, the environment is presenting an alternative vision of the future, a reorganization leading to the growth of a new ecological cycle. Within this system, the more energy a plant devotes to recovery—or defense, in a broader context—as opposed to growth, the longer it will live (Del Tredici 1999). Using the concept of rejuvenation and working within the morphological characteristic of sprouting in temperate trees, a plant's natural capacity towards recovery can be operationalized to respond to noticeable, or uncharacteristic stresses in the environment. This project proposes that the temporality of plant formation be applied to the shifting coast in order to develop green infrastructure that actually performs. As of yet, individual plants and their impact on the micro-conditions that amalgamate through biological evidence have been overlooked in the development of coastal resilience.

A hurricane is an example of swift destruction whether or not it is elevated through climate narratives. As sea levels rise, hurricanes are having greater impact along coastal environments, due to a host of phenomena including higher water tables, erratic surge, and stronger winds (Emanuel 2008). Further evidence has proven that its influence is aggravated by an increase in surface water temperatures, which creates more vapor and stronger lift (Emanuel 2005). In every case, the storm is also disturbance to terrestrial ecosystems. In ecological terms, this external force instigates an adaptive cycle on the land as energy is allocated to a systems recovery, rather than on producing new structure or material (Chapin et al. 2009; Holling 1986; Walker et al. 2004). Holling termed this phase 'creative destruction' (2001). Therefore, disturbance instigates a reorganization, and creates time and space for an altered system to emerge. More resilient systems recover rapidly, while more mature, rigid systems are slower to recover (and thus less resilient) due to closed cycles of accumulation and storage.

Derived from its lineage in systems ecology, resilience is a value typically associated with the scale of an ecosystem rather the scale of an individual organism. As a result, resilience is likened to the ambitions of conservation and landscape planning in a way that lends it nostalgic currency.[1] Building back conflates past and

[1]I borrow the term nostalgia from Svetlana Boym in *The Future of Nostalgia*, where she differentiates between nostalgia as a state-building initiative as opposed to a personal project. With this in mind, I propose that restoration is used nostalgically as means to restore the greatness of former ecologies, rather than focus on its transitions or the negative impact of human influence, sanctioning the funds for a construction project rather than initiating a change in behavior: "*What is crucial is that nostalgia was not merely an expression of local longing, but a result of a new understanding of time and space that made the division into "local" and "universal" possible.*

present, heightening the longing for a previous state, when homes were not lost, species did not invade and hurricanes were tame. In much the same way that conservation narratives generated protection rather than management, the influence of restoration when it is linked to resilience only refines a prefix—rebuilding, recuperation, restoration, reconstruction—cashing in on the green and grey infrastructures that are repaired and restored following an event. This backward momentum inhibits the future and trivializes the role of resilience.

The allure of stability and predictability underlies the success of ecological restoration within coastal development projects, as regional manifestations of climate change remain uncertain. Accordingly, local strategies prioritize known management practices and known ecologies, which estimate visual rather than functional attributes (Hilderbrand et al. 2005). For instance, along the evolving North Atlantic coast, as beaches erode and recede, pressure is put on the adjacent land that once profited from coastal low lying conditions and wide-open vistas. As fringing beaches and salt marshes attenuate or shrink with the dynamics of a changing climate, the higher, more solid ground and upland ecology emerges as the future coastline (Fig. 8.2).

The land that once served as a backdrop for coastal lifestyles is slowly becoming an edge condition. The only actions prohibiting this ecological shift to high ground are the restoration projects that promote dredge as a means to elevate salt marshes and the re-nourishment projects that raise beach profiles. These changing conditions are the systems that help create space for vegetal migration, so that the plants of the vertical high ground can gradually creep into the lower areas, sending seeds and spouts closer to the shore as conditions change. In many ways, upland plants are trying to secure bottomland habits. This is evidenced by marsh migration— the ongoing subsidence that is evidenced as *Phragmites* sp. replaces *Spartina* sp., disturbed by fluctuating hydrologic cycles. Local ecologists tend to be aware of these shifts, but their tools are limited to documentation of extents and the measure of increased fluctuations.[2] Despite their immediate and visual impact, these changes invite a productive exchange of plant life, as a different communities emerge when conditions shift.

Rhode Island: The Ocean State

Rhode Island is a small state with a long shoreline. Residents are quick to claim that no one lives further than half an hour from the shore. Also known as the 'Ocean State,' its shoreline extends inland along multiple waterways including large bays,

(Footnote 1 continued)

The nostalgic creature has internalized this division, but instead of aspiring for the universal and the progressive he looks backward and yearns for the particular."

[2]Ongoing conversations with director of restoration at 'Save the Bay,' Wenley Ferguson, reinforce this local frustration. See also SAMP reports such as: http://www.beachsamp.org/wp-content/uploads/2015/06/Rhode-Island-Sea-Level-Affecting-Marshes-Model-Technical-Report-11.pdf (accessed March 12, 2016).

Fig. 8.2 The Upland and Lowland condition is most visible from within the low-lying salt marshes, which are generally attenuating due to hydrologic disturbance. Current restoration practices tend to favor elevating the salt marsh with dredge, rather than appreciate its transformation towards open water. *Credit* Author (2014)

rivers, coves and streams. Consequently, communities are sensitive to the immediacy of littoral shifts and aware of their vulnerability within the context of coastal dynamics and seasonal hurricanes. This is especially the case in Narragansett Bay, a mixed estuary that bisects Rhode Island in a north-south direction. Providence lies at the northern reaches of the bay and Newport sits on the southern periphery. Shoreline types include fringing and meadow salt marshes, bulkhead and other modified perimeters, which comprise 25% of Narragansett Bay's perimeter.[3] Its

[3]The Bay extends approximately 45 km along this north-south axis, reaches 18 km at its widest point, and covers an area of 342 km^2. For more details on Bay dynamics: http://www.savebay.org/bayfacts.

coastal areas feature a combination of considerably disturbed sites, preserved marshland or post-industrial fill. Narragansett Bay's estuarine condition makes it unique along the highly developed Atlantic coast, as it has resisted coastal engineering such as seawalls and surge barriers.

Relative to other North Atlantic states, coastal development is limited in Rhode Island. The low density, coupled with its wealth of natural features and a strong network of environmental stewardship, positions the State to become a leader in coastal resilience, offering an exemplary model to other coastal and estuarine populations along the coast that are facing similar risks. The range of eco-tones at the land-sea (aquatic-terrestrial) interface includes numerous inland ponds, salt marshes, and coastal dunes (Fig. 8.3. Rhode Island State Map). The mucky threshold between land and water is both sandy and flat: a slim horizontal field that is perpetually shifting to open water, inch by inch. Local ecologists have been tracking and monitoring this trend, yet current environmental authority only sanctions its restoration, leaving little opportunity for a change in practice for local organizations.[4] As the shore subsides, the firmer, higher metamorphic rock of the upland materializes as the potential future waterfront: a steep, rocky coastline substitutes a flat, granular shoreline.[5] The feedback between ecology and geomorphology forms this critical eco-tone, which is transforming due the increased frequency of periodic inundation.

Most of Rhode Island's oceanfront property is privately owned. In theory, this leaves proprietors facing the prospect of lost land with only two options for their parcel: sell their lot at a net loss or elevate vertically. The municipality is also left with few actionable options: defend the beach for its economic value, protect the road for the community, or appeal for a planning strategy that acknowledges retreat. According to the Rhode Island Coastal Resources Management Council, retreat is quickly becoming a feasible proposition.[6] Retreat as a strategy promotes resettlement to higher ground or a permanent relocation, simultaneously acknowledging the authority of sea-level and its breaching of human jurisdiction. As retreat becomes more and more feasible, the question of how to use, manage, or zone the abandoned plots and lands deserves deliberation. Coupling the subsidence of the intertidal zone with the creation of increased state land holdings through resettlement and relocation reveals the opportunity to reshape the coastline as both a novel resilient ecology and a remarkable new public space.

The ecological transitions initiated by disturbance and altered hydrology can be perceived most directly in local plant life, as seed dispersal, colonization, and

[4]With particular appreciation to Wenley Ferguson (Ecologist, Save the Bay) and Janet Friedman (Coastal geologist), at CRMC for leading numerous site visits.

[5]In the case of Rhode Island, that scale of subsidence would result in a significant area of land loss, up to 20% of its total land area.

[6]http://www.crmc.ri.gov.

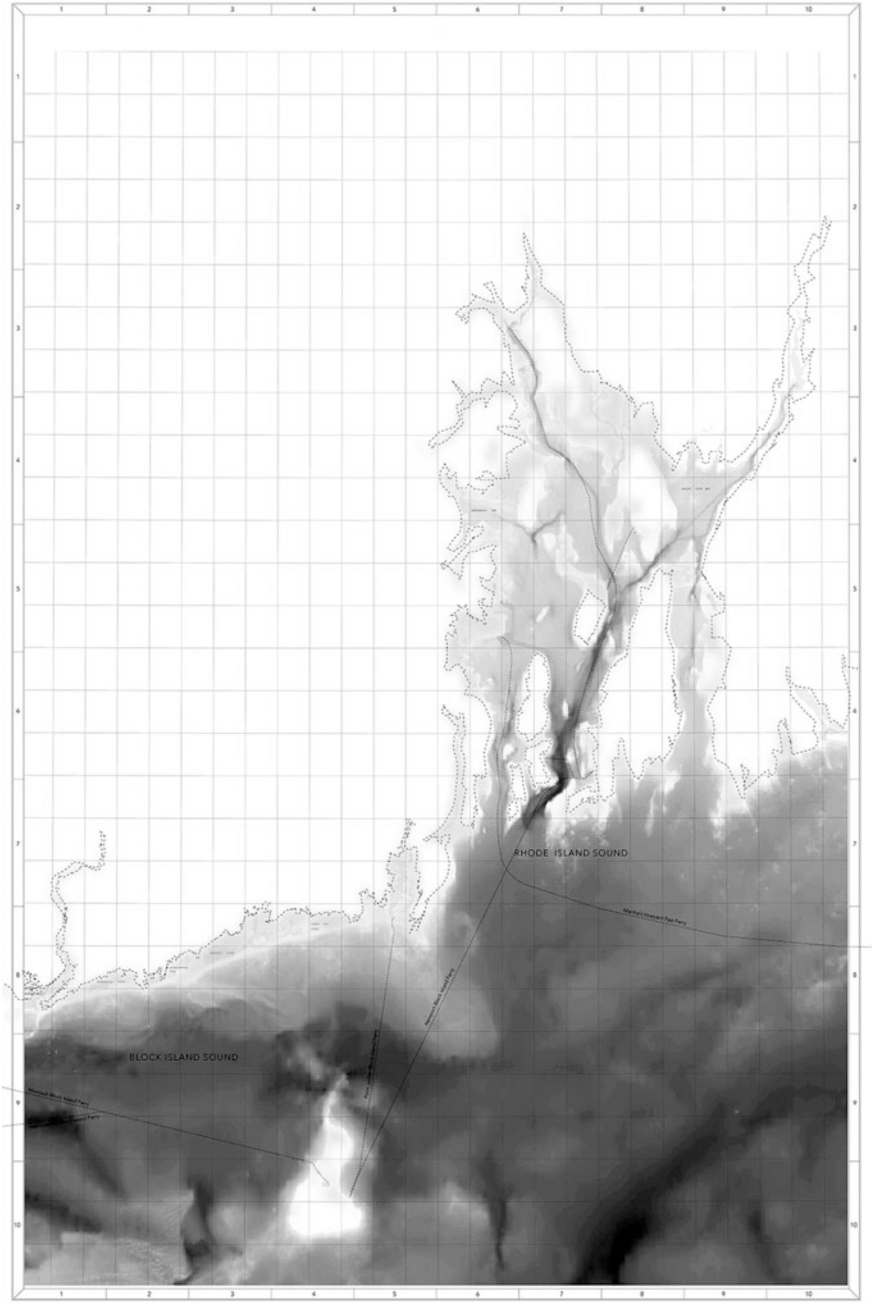

Fig. 8.3 Rhode Island sound is a rich coastal estuary where shoreline movement will undoubtedly impact its extended shores. This projection traces the margins between lowland and upland ecology. *Credit* Ocean State project

reproduction are instigated. Some plants wilt and dieback (the gradual decay of shoots), while others develop the means to prosper gaining competitive advantage. The new challenge is not how to control or halt their spread, but how to praise and encourage it. If plant life is adapting most rapidly to a changed condition, then the model for resilience cannot be reduced to restoration, but lies in the embedded intelligence of the plants that survive and flourish with shifting conditions. Simply stated, as the coastline recedes, it creeps closer to a shelf of higher ground, which is comprised of dense, mixed woodlands. If the intertidal lowland and bottomland is no longer artificially elevated with dredge and the beaches were no longer nourished by imported sand, then open water would dominate and the upland would likely become the new coast.[7] Examining the transitional species that have appeared and flourished post-hurricane Sandy suggests that given the appropriate conditions, upland species can thrive in bottomland sites (Fig. 8.4, Sassfrass sp. in a tidal marsh). Plants are adapting quickly, and, while they might move slowly, they are nonetheless always trying to gain advantage, to compete with other species and advance. In this case, they may even be outcompeting humans in their appropriation of the coast.

Operation Resilience

The word resilience did not enter contemporary usage until well after its first acceptance into ecology in 1973.[8] The word was cleverly appropriated from its application to elasticity gradients in material sciences by the prominent ecologist C. S. Holling in order to help him explain complex systems dynamics. The term has a well-documented foundation that has been heavily debated, but in every case the current definition embraces the notion of a return to stability, implicit in the objectives of recovery (McAslan 2010; Folke et al. 2010). Resilience thus tends to be juxtaposed against disturbance. It does not evoke low stability, volatile states or non-equilibrium. Instead, it has come to suggest a kind of inherent stability or toughness. When we think of resilience in 2016, we think of strength, perhaps nowhere captured more obviously that in the title of New York City’s post-Sandy reconstruction plan, “A stronger, more resilient New York” (Bloomberg 2013). When Holling introduced the term to systems ecology, the world had not yet invented a ‘superstorm’ and climate change narratives had not touched ground. The misuse and over-appropriation of the term resilience over the past decade is a direct

[7]This speculation is based on conversations between the author, Dr. Del Tredici and Grover Fugate at a meeting in June 2014 at ‘Save the Bay,’ Providence, Rhode Island.

[8]W. Skeat in A Concise Etymological Dictionary of the English Language first defined the term. (Oxford: Claredon 1882) The origin is traced by the Latin root *resilire*, which translates to ‘leap back’. Subsequent to this, it is defined by The Oxford Advanced Dictionary (2016) as the “ability (of a person or animal) to withstand or recover quickly from difficult conditions.” A clear modification from its original application and principle etymology.

Fig. 8.4 This stand of Sassafras trees is located at the edge of a salt marsh near open water, thriving only 2 years after Hurricane Sandy made landfall. *Credit* Author (2014)

result of the funding surge that followed Hurricanes Sandy and Katrina. In other words, resilience has slowly evolved from a noun into a concept that encompasses all procedures, policies, and operations that are symptomatic of adversity. As such, we risk it going the wayside with other dated neologisms (Károly 2011; Friend and Moench 2013; Benson and Craig 2014). In particular, resilience has become an expression of recovery that implies a level of stability that is both local and feasible, fostering fantasies of a 'return' to a state of normalcy—the literal bouncing back that currently leads the discourse. The liberal application of the term invites a passionate nostalgia for a time prior to the disturbance, a moral authority that fosters the reinstating of former ecologies and advances the paradigm of restoration.

Yet, when Holling appropriated the term resilience, he applied it suggestively to time rather than space, using evidence collected through observation of behavior, amplitude, and frequency of oscillations: "*Individuals die, populations disappear, and species become extinct*" (Holling 1973). By relating it to duration, he could justify monitoring periods of dormancy and decline in an ecosystem, charting the intervals of recovery. Holling proposed that when considering the performance of systems, attention ought to emphasize the conditions and time-scales that allow organisms to persist, rather than targeting momentary equilibrium states which overlook dynamic values. Therefore, he revealed the association or amount of impact from a disturbance could either result in the absorbance of a shock or in an alternative configuration. Prior to this suggestion, single equilibrium assumptions had dominated the global stability of ecological thought. Holling's 'multi-stable state reality' revealed instability as a predictable outcome, an important attribute of the behavior of ecological systems (Gunderson et al. 2010). The term resilience was applied as a means to designate this novel form of instability, one that was predicated on high variability and behavior expressed far from equilibrium. Time became a generative feature of ecological theory as Holling ascertained that the most resilient systems are simultaneously those that display low stability.

The notion that resilience references a future condition, rather than retrospective one, offers expanded opportunities to the discourse that surrounds coastal design strategies. Further, the modifications that disturbance-based events create ought be respected and evaluated as a measure of ecological resilience (Gunderson 2000). This line of inquiry also profoundly denies the image of a hopeful past, as evidenced through the success of 'before and after' images that propagate following coastal storm events. Such popular documentation invokes past states by vividly indexing what has been lost or destroyed. Each photograph signifies an effort to record the hard times of the present, by expressing a convincing fiction of prosperity and stability about the past. Images of this kind suggest that restoration to former states is a tradition of progress and a virtue that can enable humans to persevere in a time of crisis: before and after and then before again. Such restorative practices negate the value of duration and time based events, sanctioning static images and creation myths: the marsh, the dune, the pond are reinstated as non-native species are eradicated and water levels are controlled by the pipes, backflow preventers, and culverts that offer long term ecological life support.

The Planted Coast

What if the loss of beachfront can be balanced by a significant gain in forest cover? It is not difficult to imagine that elevated boardwalks and tents can replace umbrellas and bikinis. Accepting a transitional coast means that in increasingly important ways, the questions that the living environment presents are about how to shape it not how to preserve it.[9] Designing a series of forests in lieu of restoring existing ecology forces a consideration of how the environment is valued and managed. In this case, deliberate species selection realizes the potential of plants to shape the environment, providing a foundation to develop a design that can be manipulated and measured alongside typical construction materials (Fig. 8.5. Selected species charts). The research proposes a design strategy that proposes to plant a considerable area of coastal forests along the intertidal zone, creating a biological fabric that is both adaptable and resilient to persistent saltwater inundation, accelerating the shifting coastal morphology. An assortment of disturbance-adapted woody trees and shrubs instigates accumulation and land accretion on hummock-like formations.[10] Construction occurs as a process. As species are selected for their ability to sprout through burls, roots, and stems, their root zone thickens and their adaptive capacity to withstand disturbance multiplies (Del Tredici 2001). Each forest can benefit from the current particulate condition, reinforced when required and planted by clumps of new species (Fig. 8.6. Design drawing, construction detail). The proposal of a novel ecosystem is equally a redesign of the coast, as grasses and sedges are replaced with shrub thickets and

[9]See Purdy, J. *After Nature: A Politics for the Anthropocene.* Cambridge: Harvard, 2015 (11).

[10]Plant lists developed in collaboration with Dr. Peter Del Tredici (see appendix).

multi-stem tree species. Coastal forests will provide essential infrastructural protection for adjacent roads and evacuation routes, including wind mitigation, debris capture, expanded recreational opportunities, and more importantly a critical setback for development that prevents more open water, as bottomlands are appropriated by rising sea levels.

Sprouts, Cuttings, and Reiteration

A tree is characteristically imagined as having one single stem, rising up to a wide and dense canopy. This particular form, while culturally valuable, makes the tree susceptible to environmental disturbances. However, if a central role for disturbance is accepted as an attribute of resilient design, then the form of the tree becomes pliable. Trees can be expected to break or fall, sprouting secondary trunks —an induced response to injury common to temperate angiosperm trees (Del Tredici 2001). This behavior can be classified into four different morphologies: root sprouts, collar sprouts, sprouts from underground stems, and layered, opportunistic sprouts (Fig. 8.7. Root morphology). Root Sprouts—more commonly known as root suckers—produce genetically identical clones that emerge from an injured or non-injured root, a feature of a many trees and shrubs of the Northeast. Collar sprouts emerge from the junction between roots and sprout, very close to the ground, and have great potential to develop secondary trunks from this point. Sprouts from underground stems dominate the rhizosphere as they emerge from underground and form adventitious roots that can often appear far from the parent tree. Finally, opportunistic sprouts are the least common, spreading through layering or reiteration. Reiteration occurs when a low-hanging branch reaches the soil, produces roots and eventually sprouts vertical shoots.

Sprouting in trees is not a biological attribute that is generally considered desirable by designers who, with the curious exception of white birches, seem to favor single stemmed specimens. This preference leads to an overreliance on stock material and planting seedlings with great labor budgets, denying the true potential of designing with plant behavior. Ultimately, such generic practices reduce the selection of plants to a desire for above-ground form, silhouette or attractive seasonal qualities, features of planning that ignore the root system. Planting with behavior in mind necessitates a profound acceptance of an environment in constant transition, for example through fluctuations in salinity levels and altered hydrologic flows. Behavior is predictive, not reflective, and equally cannot help to restore former plant communities or associations. In order to establish a planted forest so close to subsidence conditions, the design relies on creating hummocks by re-distributing fill (Fig. 8.8. Design drawing plan). Plants are introduced on higher elevations, eventually holding the ground and spreading laterally as the soil accumulates. The ability of plants to colonize the ground and build soil becomes a critical consideration in the design proposal, especially relevant now that the challenges have been scaled irreversibly by the complexity of climate change.

	Root Suckering Species	Stump Sprouting Species	Burl Sprouting Species	Conifers (non-sprouting)
Bottomland Species	Acer negundo* Asimina triloba# Liquidambar styraciflua *# Nyssa sylvatica	Acer rubrum Acer pseudoplatanus*+ Acer saccharinum Alnus glutinosa*+ Alnus meritima*# Betula nigra# Catalpa speciosa *# Celtis laevigata# Gleditsia triacanthos* Ilex opaca Magnolia virginiana# Platanus occidentalis* Platanus x acerifolia *+ Populus deltoides* Quercus bicolor* Quercus palustris * Quercus phellos*# Salix nigra* Salix fragilis+		Chamaecyparis thyoides* Larix decidua+ Larix laracina Picea mariana Taxodium distichum*# Thuja occidentalis Thuja plicata+
Upland Species	Diospiros virginiana# Fagus grandifolia Gymnocladus dioicus*# Maclura pomifera*# Populus tremuloides* Prunus virginiana% Robinia pseudoacacia* Sassafras albidum *	Aesculus hippocastanum*+ Amelanchier arborea Betula lenta Carpinus caroliniana Carya cordiformis Carya tomentosa* Celtis occidentalis Juglans nigra* Koelreuteria paniculata*+ Prunus serotina * Quecus acutissima+ Quercus coccinea Quercus rubra* Sorbus alnifolia*+	Ginkgo biloba+ Magnolia acuminata# Quercus alba Tilia americana* Tilia cordata*+	Juniperus virginiana* Picea abies+ Picea glauca* Picea pungens* Pinus heldreichii*+ Pinus mugo*+ Pinus parviflora*+ Pinus rigida* Pinus strobus Pinus thunbergii*+

*Species with some degree of salt-tolerance
#Southern species
+Non-native species
%Rhizomatous species

Note: Bottomland species grow well in upland conditions, but not vice versa

Fig. 8.5 Selected resilient and sprouting tree species chart. *Credit* Ocean State project and Dr. Peter Del Tredici

Exploiting the sprouting and regrowth of the living tree stump, or stool, is a common to coppice forestry, a practice that produces significant economic value. Yet, the biological benefits are less culturally notable since the root zone lies out of sight and makes no significant capital contribution. Characteristically, these forests are valued for the poles or whips that provide firewood, fence material, and such. But, the ability of seedlings or roots to resprout following damage actually enhances their survival through disturbance is less known. Further, individuals that

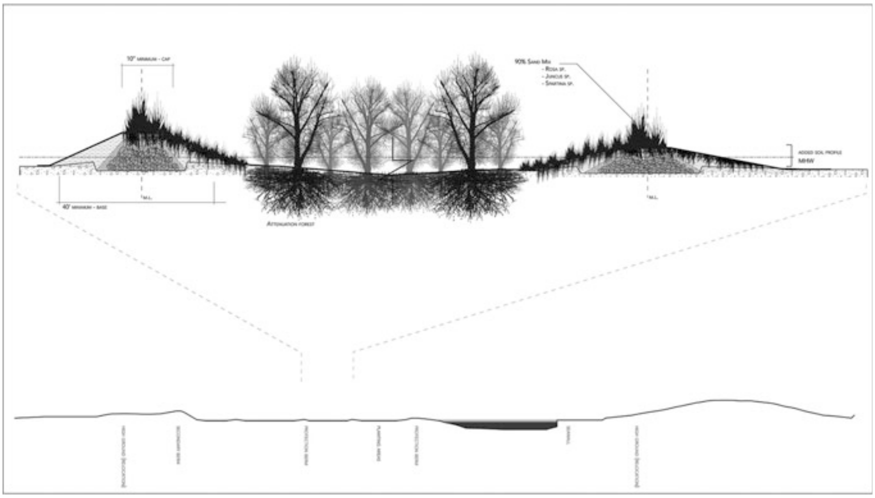

Fig. 8.6 The interaction between hardened and softened infrastructure is drawn in section to describe how the landform helps to attenuate, protect and control inundation. *Credit* Ocean State project

Fig. 8.7 Three types of tree sprouting morphologies from *left*: Root Suckering, Stump Suckering and Burl Sprouting. *Credit* Dr. Peter Del Tredici

grow and adapt to disturbed sites are likely to grow more vigorously and retain their sprouting ability longer than those who undergo less stress (Del Tredici 2001). This is evidenced by the number of ancient stools around Europe, the physical result of hundreds of years of coppicing. In much the same way, the trees selected for this project simply adapt to disturbance by living longer and getting stronger, as their

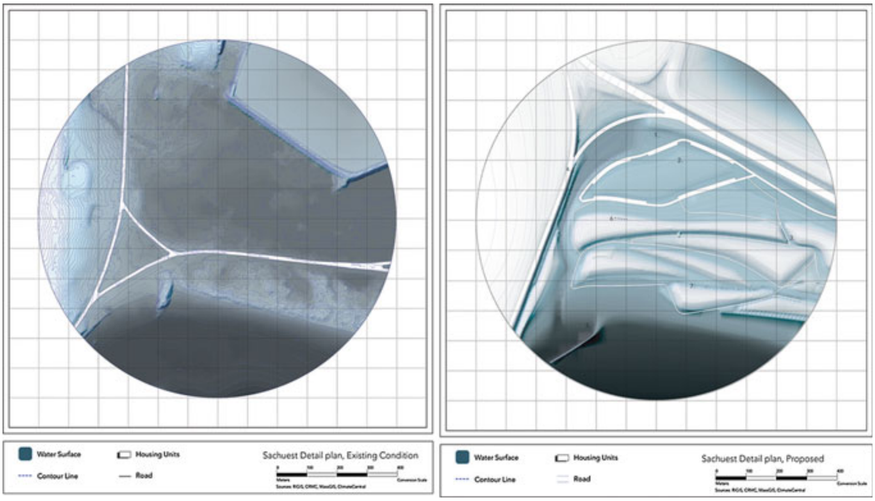

Fig. 8.8 Typical design plan. The typical attenuation backfill from the former condition (*left*) to the future, indicating programmatic potential before planting (*right*). *1* visitor parking, *2* picnic areas, *3* multi-use trail, *4* re-aligned river, *5* maidform river jetty, *6* transverse dune, *7* fore-dune system. *Credit* Ocean State project

structures below ground thicken to promote survival. Such morphological features actually exploit disturbance in order to build and confirm resilience.

The research relies on known morphological behaviors, rather than unpredictable horticultural features. By relying on disturbance and integrating maintenance into the initial concept, the design is necessarily time based, as upkeep is imagined though rigorous cycles of pruning and mowing so that the entire tree can become more durable in the face of strong winds and erosive waves. These forests of multi-stemmed, disturbance-adapted specimens are predicted to reproduce, creating restructured woodlands that can be both productive and resilient in the face of change. Imagining stands of clonal, fragrant *Sassafras* sp., against tall, green mounds of *Rhus* sp. and groves of multi-stemmed *Tilia* sp., or dense suckering thickets of *Cornus* sp., implies a different image of the temperate forest, one that forces a reevaluation of resilience. Reconsidering plant species and the role of plants provides novel ways to harness disturbance as a mechanism for building and strengthening.

Future Resilience

Modern resilience is paradoxical in the sense that the universality of its application in sanctioning the restoration of landscape features. This universal acceptance reinforces the notion that recovery is predictable and familiar, an acknowledgment that engenders a false sense of stability. At the scale of the community and within the regulatory environment, reconstruction efforts support restorative practices. While the intentions themselves are progressive, this research argues that the design professions are not taking the notion of instability and disturbance seriously, since the meaning of resilience is often misunderstood or ill defined. If high resilience can only be achieved through the modifications embedded in low stability, and if the outcomes often reveal new configurations, then renovating a seawall, restoring a salt marsh, or renourishing a dune are the lowest possible forms of building resilience and the highest form of securing failures. The promise to rebuild or restore lies at the core of this misapplication, so that resilience as a term loses meaning, and is reduced to a label that can only help make sense of the fear of destruction. Misapplication is especially explosive along the urbanized coast, where design projects are being implemented in record numbers due to the authority of resilience funding. A closer consideration of the defining features of resilience can increase the motivation for a change in status quo, endorsing novel ecologies, adaptable species, and alternative programs in order to draft a new image of the coast. The proposition deflates the unproductive dichotomy between green and grey systems and elevates the role of plants in the paradigm of resilience.

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References

Adger WN, Brown K, Nelson DR, Berkes F, Eakin H, Folke C, Galvin K, Gunderson L, Goulden M, O'Brien K, Ruitenbeek J, Tompkins EL (2011) Wiley Interdisc Rev: Climate Change 2(5):757–766

Bennett O (2001) Cultural pessimism: narratives of decline in the postmodern world. Edinburgh University Press, Edinburgh

Benson MH, Craig RK (2014) The end of sustainability. Soc Nat Res: Int J 27(7):777–782

Bloomberg M (2013) A stronger, more resilient New York. City of New York, New York

Chapin FS III, Gary P Kofinas, and Carl Folke (2009) A framework for understanding change. In: Chapin FS III, Kofinas GP, Folke C (eds) Principles of ecosystem Stewardship: resilience-based natural resource management in a changing world. Springer, New York, New York, USA

Del Tredici P (1999) Aging and rejuvenation in trees. Arnoldia. Winter:11–16

Del Tredici P (2001) Sprouting in temperate trees: a morphological and ecological review. Bot Rev 67(2):121–140

Emanuel KA (2005) Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436:686–688

Emanuel KA (2008) The hurricane-climate connection. Bull Am Meteorol Soc 89

Friend R, Moench M (2013) What is the purpose of urban climate resilience? Implications for addressing poverty and vulnerability. Urban Climate 6:98–113

Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J (2010) Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc 15(4)

Gunderson LH (2000) Ecological resilience—in theory and application. Ann Rev Ecol, Evol, Syst 31:425–439
Gunderson LH, Allen CR, Holling CS (2010) The evolution of an idea—the past, present, and future of ecological resilience. In Gunderson LH, Allen CR, Holling CS (eds) Foundations of ecological resilience, pp 1–13
Hilderbrand RH, Watts AC, Randle AM (2005) The myths of restoration ecology. Ecol Soc 10(1)
Holling CS (1973) Resilience and stability of ecological systems. Ann Rev Ecol Syst 4:1–23
Holling CS (1986) Resilience of ecosystems: local surprise and global change. In: Clark WC, Munn RE (eds) Sustainable development and the biosphere. Cambridge University Press, Cambridge, UK, pp 292–317
Holling CS (2001) Understanding the complexity of economic, ecological, and social systems. Ecosystems 4(5):390–405
Hollnagel E (2009) The four cornerstones of resilience engineering. In Nemeth Christopher P, Hollnagel E, Dekker S (eds) Resilience engineering perspectives: preparation and restoration. Ashgate, Farnham, UK
Károly K (2011) Rise and fall of the concept sustainability. J Environ Sustain 1(1):1
McAslan A (2010) The concept of resilience: understanding its origins, meaning and utility. Torrens Resilience Institute, Adelaide
Purdy J (2015) After nature: a politics for the anthropocene. Harvard, Cambridge
Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social–ecological systems. Ecol Soc 9(2):5