CHAPTER 13

Resilience Beyond Rhetoric in Urban Landscape Planning and Design

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On December 21, 2013, the city of Toronto and its metropolitan area of five million inhabitants—along with a sizeable portion of southern Ontario and northern New York—experienced an unseasonably warm winter storm. The storm dropped more than 1.2 inches (30 millimeters) of freezing rain on the city. Temperatures hovered around freezing for almost 36 hours and then rapidly plummeted to -13°f (-25°c) and stayed there, locking the city under a blanket of ice for almost two weeks and leaving more than half a million residents in the frozen dark following the winter solstice. Under the weight of the ice, more than 20 percent of the city's 10 million trees were felled, bringing down power lines and cables in the process and leaving thousands of homes without power, heat, or light through Christmas and the holiday season. With an estimated cost of $106 million Canadian to the city of Toronto alone in clean-up and emergency services, the eastern North American ice storm of 2013 is recorded as one of the worst natural disasters in Canadian history.[1] Yet, notably, this figure does not account for the loss of the green infrastructural value and the attendant ecosystem services of the loss of one-fifth of the city's mature tree canopy. The city will continue to suffer long-term related impacts of the ice storm through increased soil erosion and decreased flood protection, carbon sequestration, urban heat mitigation, and so on (figs. 13.1 and 13.2).

The ice storm, however, was not an isolated incident. In February 1998, a similar ice storm caused a massive power outage throughout Quebec that lasted more than two weeks, affecting more than 50,000 homes in the middle of a deep freeze. The Red River floods of 1998 and 2012 crippled the cities of Winnipeg, Minneapolis, and St. Paul, while Alberta's Bow River flood of 2012 virtually shut down the city of Calgary and the Trans-Canada Highway (Route Transcanadienne) for more than a month. These are but a few of many recent, locally catastrophic storm

OPPOSITE

Fig. 13.1. The city of Toronto's skyline following the famous 2013 North American ice storm. Increasingly, cities worldwide are confronting a changing climate in many ways that challenge an existing infrastructure. Photograph by "Raysonho" and licensed under Creative Commons 1.0 Universal Public Domain Dedication (https://creativecommons.org/publicdomain/zero/1.0/deed.en).

Fig. 13.2. Fallen tree branches and downed power lines were ever-present following the 2013 ice storm that left thousands without electricity. Photograph by Ron Bulovs and licensed under Creative Commons Attribution 2.0 Generic license (http://creativecommons.org/licenses/by/2.0).

events. The better-known "monster storms"—such as Hurricanes Katrina, which devastated New Orleans and the Gulf Coast in 2005, and Sandy in 2012, which devastated the New Jersey, New York, and Connecticut shores and left half of mid-town Manhattan without power for more than a week—are globally significant events. By virtue of their reach and effect in major urban centers, these storms have catalyzed a new wave of research into urban environmental planning, coastal defense, urban vulnerability, and related policy responses that link urbanism, planning, and ecology.

In addition to the economic, social, and environmental costs of such storms, there is growing recognition that these events pose significant challenges to our respective systems of governance and planning. Cities throughout North America and the globe are facing the reality that the increasing magnitude and frequency of major storm events are evidence of human-induced global climate change, and with this reality has come a range of increasing challenges to our systems of survival, including a need for new design approaches to cope with ecological change and vulnerability.[2] Identified as a global threat by the International Panel on Climate Change and grounded in a wide range of policy-related research linked to long-term sustainability, climate change is now an accepted phenomenon for which adaptation strategies must be developed and implemented from municipal to national scales.[3] This view was reinforced at the international accord on climate change in Paris, France, in December 2015.

Long-term environmental sustainability demands the capacity for resilience—the ability to recover from a disturbance, to accommodate change, and to function in a state of health. In this sense, sustainability refers to the inherent and dynamic balance among social-cultural, economic, and ecological domains of human behavior that is necessary for humankind's long-term surviving and thriving. Ann Dale has described this dynamic balance as a necessary act of reconciliation among personal, economic, and ecological imperatives that underlie the primordial natural and cultural capitals on Earth.[4] With this departure from conventional "sustainable development," Dale has set the responsibility for long-term sustainability squarely in the domain of human activity, and appropriately removed it from the ultimately impossible realm of managing "the environment" as an object separate from human action.

A growing response to the increasing prevalence of major storm events has been the development of political rhetoric around the need for long-term sustainability and, specifically, resilience in the face of vulnerability. As a heuristic concept, resilience refers to the ability of an ecosystem to withstand and absorb change to prevailing environmental conditions. In an empirical sense, resilience is the amount of change or disruption an ecosystem can absorb, by which, following these change-inducing events, there is a return to a recognizable steady state in which the system retains most of its structures, functions, and feedbacks.[5] In both contexts, resilience is a well-established concept in ecological systems research, with a robust literature related to resource management, governance, and strategic planning. Yet, despite more than two decades of this research, the development of policy strategies and planning applications related to resilience is relatively recent. While there was a significant political call for resilience planning following Hurricane Sandy in 2012 and the ice storm of 2013, there remains a widespread lack of coordinated governance, established benchmarks, implemented policy applications, and few (if any) empirical measures of success related to climate change adaptation.[6] In this context, there has been little critical analysis of and reflection on the need to understand, unpack, and cultivate resilience beyond the rhetoric. In this essay, I argue that concomitant with the language of resilience is the need to develop nuanced, contextual, and critical analyses coupled with a scientific, evidence-based understanding of resilience; that is, we need an evidence-based approach that contributes to adaptive and ecologically responsive design in the face of complexity, uncertainty, and vulnerability. Put simply: What does a resilient world *look* like, how does it *behave*, and how do we plan and design for resilience?

Fig. 13.3. Four views of a washed-out section of a major arterial roadway in Toronto after heavy rain and flooding of the Don River followed Hurricane Katrina, which was downgraded to a tropical storm when it hit Toronto on August 29, 2005. Photo-collage by Carmela Liggio and Nina-Marie Lister, 2005.

Why Resilience? Why Now?

The emergence of resilience as a rhetorical idea is tied not only to the emerging reality of climate change, but to an important and growing synergy between research and policy responses in the fields of ecology, landscape architecture, and urbanism—a synergy that is powerfully influenced by several remarkable and coincidental shifts since the turn of the second millennium. Most notable is the shift in the world's population, in which our contemporary patterns of human settlement are trending hard and fast toward large-scale urbanization. The last century has noticeably been characterized by mass migration to ever-larger urban regions, resulting in the rise of the "mega-city" and its attendant forms of suburbia, exurbia, and associated phenomena of the modern metropolitan landscape.[7] For most of the world's population, the city is fast becoming the singular landscape experience.[8]

In North America, in general, and the United States, in particular, this shift in urbanism has come, paradoxically, with a widespread decline in the quality and performance of the physical infrastructure of the city. The roads, bridges, tunnels, and sewers that were built during the late nineteenth and early twentieth centuries to service major urban centers are now aging and crumbling, in some cases, while both the political will and the public funds to rebuild this outdated but essential public infrastructure are disappearing. More significantly, these infrastructures continue to decay, and they are increasingly vulnerable to catastrophic failure in the face of more frequent and more severe storm events, thus compounding the cost of loss and the extent of impact (fig. 13. 3).

The emergence of a new direction and emphasis in ecology represents another significant and concomitant shift with a change in urbanism and the reality of climate change. During the last few decades, the field of ecology has moved from a classical, reductionist concern with stability, certainty, predictability, and order in favor of more contemporary understandings of dynamic, systemic change and the related phenomena of uncertainty, adaptability, and resilience. Increasingly, these concepts in ecological theory and complex systems research are found useful as heuristics for decision-making in general and, with empirical evidence, for landscape design specifically.[9] This offers a powerful new disciplinary and practical space—one that is informed by ecological knowledge both as an applied science and as a construct for managing change within the context of sustainability. As a practice of planning *for and with* change, resilience is, in itself, a conceptual model for design.[10]

With this new ecological approach has come another important shift in creating the synergy necessary for resilience-thinking: the renaissance of *landscape* as both a discipline and praxis throughout the last two decades and its (re)integration with planning and architecture in both academic and applied professional domains. Landscape scholars have identified the rise of postindustrial urban landscapes coupled with a focus on indeterminacy and ecological processes as catalysts for the reemergence in landscape theory and praxis.[11] Understood today as an interdisciplinary field linking art, design, and the material science of ecology, landscape scholarship and its application now includes a renewed professional field of practice within the space of the city.[12]

Considered together in the era of climate change and vulnerability, these shifts in our collective understanding of urbanism, landscape, and ecology have created a powerful synergy for new approaches in planning and design to the contemporary metropolitan region. This synergy has been an important catalyst for the emergence of resilience as a rhetorical idea, but much work remains to be done to move toward evidence-based implementation of strategies, plans, and designs for resilience. The scale and impact of North American mega-storms such as Hurricanes Katrina and Sandy have been effective triggers for a new breed of policy and planning initiatives in disaster preparedness overall, and flood-management specifically.

Conventional policy and planning approaches to natural disasters have long been rooted in the language of *resistance* and *control*, referencing coastal defense strategies such as fortification, armoring, and "shoring up" by using brute-force engineering responses designed to do battle with natural forces.[13] By contrast, emerging approaches in design and planning reference the language of *resilience* and *adaptive management*, terms associated with elasticity and flexibility, leading to the use of hybrid engineering of constructed and ecological materials that adapt to dynamic conditions and natural forces.[14] Recent coastal management policies and flood management plans following the major storm events abound in this language of resilience, including the Greater New Orleans Urban Water Plan (2013), Louisiana's 2017 Coastal Master Plan, New York City's Rebuild by Design program (2013), and Toronto's Wet Weather Flow Master Plan (2003). These examples are notable responses (reactive and proactive) to catalytic storm events and climate change, yet they remain, for the most part, speculative, untested, and unimplemented, relying on a language of resilience that is heuristic and conceptual rather than experiential, contextual, or scientifically derived.

The general concept of resilience has origins across at least four disciplines of research and application: psychology, disaster relief and military defense, engineering, and ecology. A scan of resilience policies reveals that the concept is widely and generally defined with reference to several of the original fields and is universally focused on the psychological trait of being flexible and adaptable—for example, of having the capacity to deal with stress, the ability to "bounce back" to a known normal condition following periods of stress; to maintain well-being under stress; and to be adaptable when faced with change or challenges.[15]

The use of resilience in this generalized context, however, begs important operational questions: How much change is tolerable? Which state of "normal" is desirable and achievable? And under what conditions is it possible to return to a known "normal" state? In policies that hinge on these broadly defined, psychosocial aspects of resilience, there is little or no explicit recognition that adaptation and flexibility may result in transformation and, thus, require the

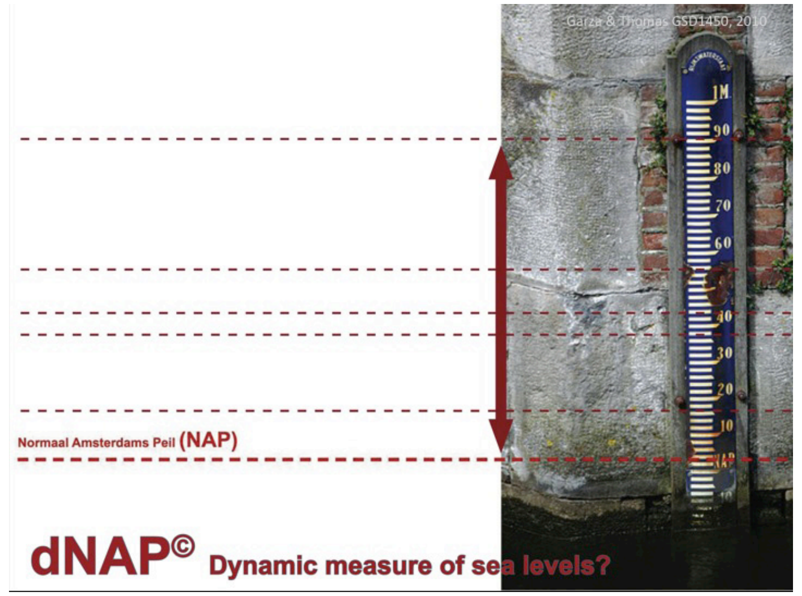


Fig. 13.4. The Normaal Amsterdams Peil (NAP) is a measure used to gauge the rise in sea level and to establish national policies, laws, and regulations on the basis of a fixed, "normal" water level. In contrast, the Dynamic Normaal Amsterdams Peil or d(NAP), shown here, is a proposed measure of sea level for the Netherlands Delta Region that acknowledges dynamic water levels to address better changing hydrological regimes; for example, to reflect seasonal flooding. Diagram courtesy of Kimberly Garza and Sarah Thomas, 2010.

transformative capacity that is ultimately necessary at some scale in the face of radical, large-scale and sudden systemic change. Using sea level as an example, if we accept that waters naturally rise and fall within a range of seasonal norms, we might be better off to embrace a gradient of acceptable "normal" conditions rather than a single static—and, ultimately, brittle—state that is unsustainable (fig. 13.4).

A more critical and robust systems-oriented discussion of resilience will force all concerned to confront a difficult but essential question: How much can an individual, a community, or an ecosystem change before becoming something unrecognizable and functioning as an altogether different entity?[16] If resilience is to be a useful concept in application and, in particular, in informing design and planning strategies, it must ultimately instruct us *how* to change safely rather than how to resist change completely. Current policies and eventual design strategies will risk the potential power of resilience by emphasizing a misguided focus on "bouncing back" to a normal state that is, ultimately, impossible to sustain.

Unpacking Resilience

Before one can implement applied strategies and associated indicators for resilience in design and planning, it is useful and, arguably, necessary to unpack the history, theory, and conceptual development of resilience as it emerged in ecology. We can do so critically with reference to a well-established social-scientific literature derived principally from ecosystem ecology and, in particular, with research applications in natural resource management. Decades of research related to complex systems ecology and thinking about and practice of socio-ecological systems offer both broad heuristic and empirical contexts for the study and application of resilience. As such, both the construct and measures of resilience are important to embed, apply, and test within respective policies and designs for long-term sustainability. As an essential capacity for sustainability, applications of resilience are derived from research in complex systems ecology, first published by Howard T. Odum (1924–2002), the American ecologist, and later developed by Crawford Stanley ("Buzz") Holling (b. 1930), the Canadian ecologist.[17] Yet it should be noted that the foundations of resilience thinking were laid earlier.

Well before the language of complex systems was embraced within ecological science, the conservationist movement during the early twentieth century was already concerned with the health of natural systems, which was conceptualized variously, from self-renewal to healing and balance with implications for management practices. For example, Aldo Leopold (1887–1948) used the concept of "land health" to refer to the land's capacity for self-renewal—essentially resilience—which he saw as threatened by and at odds with unchecked exploitation of land and resources for economic growth.[18] Similarly, Gifford Pinchot's (1865–1946) perspectives on the need for cautious resource extraction, however utilitarian, gave rise to an early version of adaptive management to accommodate changes in nature and the landscape.[19] By the 1960s, with the birth of modern environmentalism, there were more urgent calls for caution. Notable among these was Rachel Carson's (1907–1964) characterization of nature as resilient, changeable, and unpredictable. As she wrote in *Silent Spring* (1962): " . . . the fabric of life . . . on the one hand delicate and destructible, on the other miraculously tough and resilient, capable of striking back in unexpected ways."[20]

The late 1970s and early 1980s marked the beginning of a significant theoretical shift in the evolving discipline of ecology. In general, ecological research at all scales has moved toward a more organic model of open-endedness, indeterminacy, flexibility, adaptation, and resilience and away from a deterministic and predictive model of stability and control, based on engineering models for closed (usually mechanical) systems. Ecosystems are now understood to be open, self-organizing systems that are inherently diverse and complex and behave in ways that are, to some extent, unpredictable.

This shift, influenced by the early ecosystem analyses of the Odum brothers (Eugene P. and Howard T.), followed the rise in complexity science and the groundbreaking work of Ilya Prigogine (1917–2003), Ludwig Von Bertalanffy (1901–1972), C. West Churchman (1913–2004), Peter Checkland (b. 1930), and other systems scholars throughout the latter half of the twentieth century. Ecological research came into its own discipline, distinct from biology and zoology, by focusing on large-scale and cross-scale (connected) functions and processes of an ecosystem. As an outgrowth of research in complex systems coupled with the emerging new discipline of landscape ecology and associated spatial analyses—made possible by new tools, such as high-resolution satellite imagery—ecosystem ecology led to multi-scaled, cross-disciplinary, and integrated approaches in land-use planning. Beginning in the 1970s with F. Herbert Bormann's (1922–2012) and Gene Likens's (b. 1935) first ecosystem-based study of the Hubbard Brook watershed, long-term ecological research programs (known as LTERPs) became established, influencing, throughout the 1980s and 1990s, a growing recognition of the dynamic processes inherent in and essential to living, layered landscapes and the understanding of ecosystems as open, complex systems within which structure and function are interrelated and scale-dependent.[21]

The dynamic ecosystem model has been an important development in ecology and a significant departure from the conventional, linear model of ecosystems that dominated scholarly thought during the twentieth century. Resilience is an important concept that emerged from this development. Defined by the process of ecological succession, the linear model held that ecosystems gradually and steadily succeed into stable climax states from which they will not routinely move unless disturbed by a force external to that system.[22] An old-growth forest is the typical example, in which a forest matures and then remains in that state permanently such that any deviation from that state is considered an aberration. Yet we now know that not only is change built into these systems, but, in some cases, ecosystems are dependent on change for growth and renewal. For example, fire-dependent forests contain tree species that require the extreme heat of fire to release and disperse seeds and to facilitate a forest's renewal and, sometimes, a shift in the complement of species following a major fire. The dynamic ecosystem model, based on long-term research in a variety of global contexts, asserts that all ecosystems go through recurring cycles with four common phases: rapid growth, conservation, release, and re-organization. Known as the adaptive cycle, or the Holling Figure 8, this generalized pattern is a useful conceptual description of how ecosystems organize themselves over time and respond to change.[23] The adaptive cycle of every ecosystem is different and contextual; how each system behaves from one phase to the next depends on the scale, context, internal connections, flexibility, and resilience of that system (figs. 13.5 and 13.6).

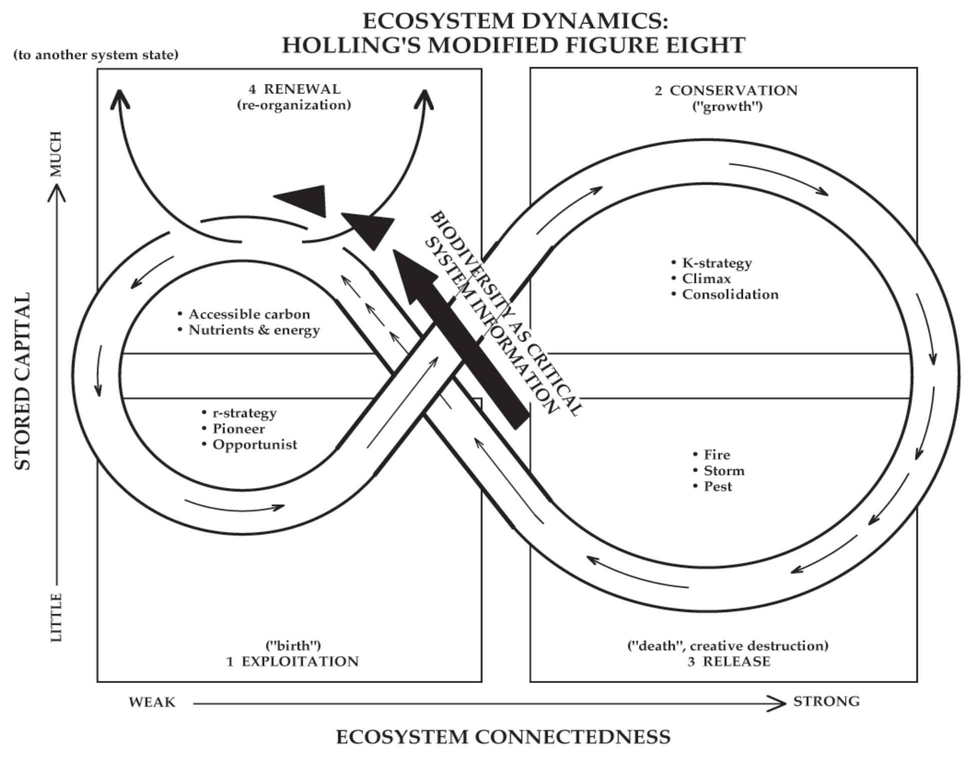


Fig. 13.5. Ecosystem Dynamics and the Adaptive Cycle: Holling's Modified Figure 8. Ecologist C. S. Holling's dynamic cycle of ecosystem development is the foundation of a complex systems perspective in ecology. Diagram courtesy of David Waltner-Toews, James J. Kay, and Nina-Marie E. Lister, eds., *The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability* (New York, NY: Columbia University Press, 2008), 97; modified from C. S. Holling, "Understanding the Complexity of Economic, Ecological, and Social Systems," *Ecosystems*, Vol. 4, No. 5 (August 2001): 390–405.

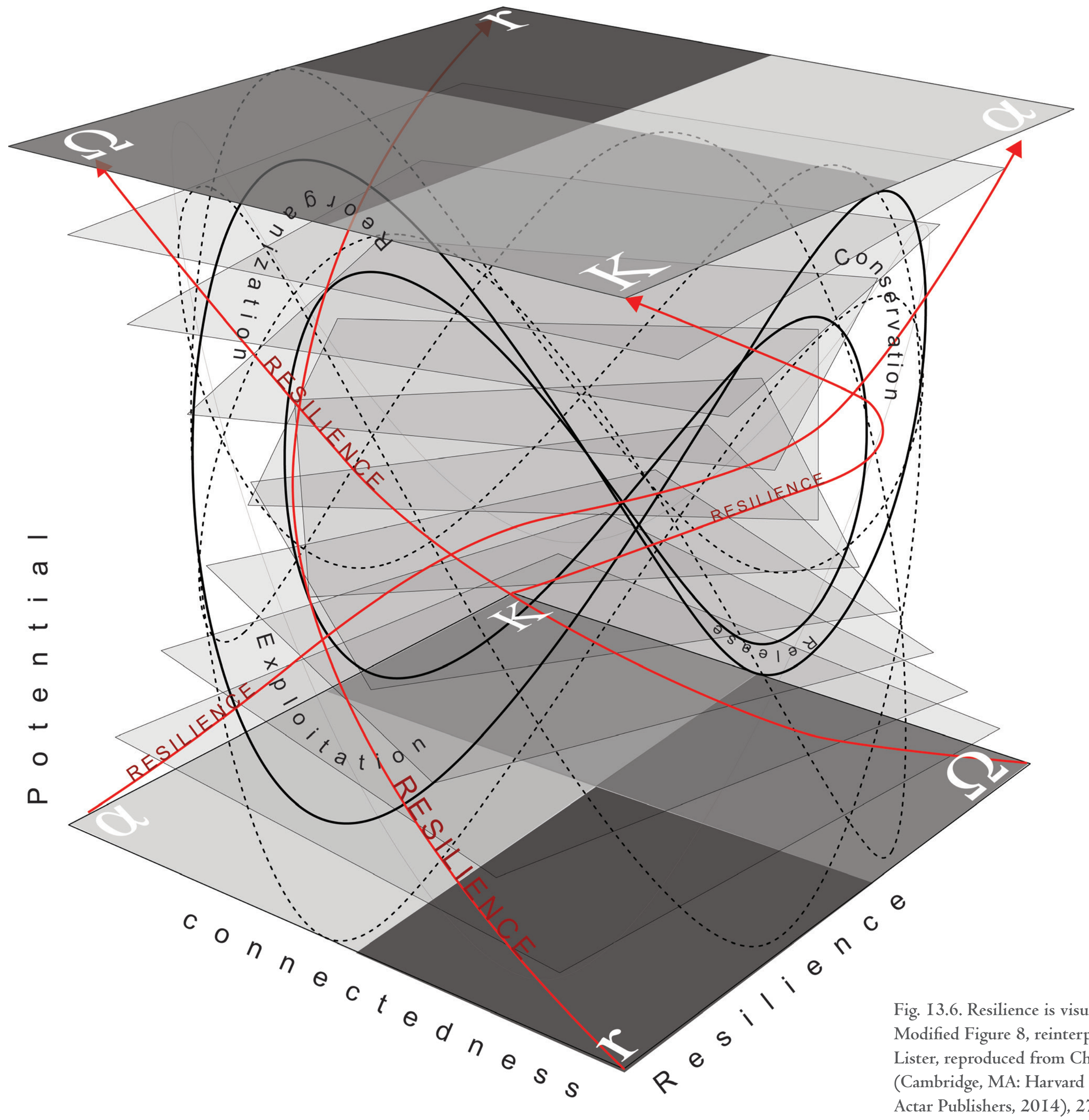


Fig. 13.6. Resilience is visualized here as a function of the adaptive cycle: Holling's Modified Figure 8, reinterpreted by Tomás Folch, Chris Reed, and Nina-Marie E. Lister, reproduced from Chris Reed and Nina-Marie E. Lister, eds., *Projective Ecologies* (Cambridge, MA: Harvard University Graduate School of Design, and New York, NY: Actar Publishers, 2014), 278.

Ecosystems are constantly evolving, often in ways that are discontinuous and uneven, with slow and fast changes at small and large scales. While some ecosystem states appear to be stable, stability is not equated in a mathematical sense but rather in a human-scale or time-limited perception of stasis. C. S. Holling pioneered this concept in application to resource management, in which he described ecosystems as "shifting steady-state mosaics," implying that stability is patchy and scale-dependent and is neither a constant nor a phenomenon that defines a whole system at any one point in time or space.[24] The key point is that ecosystems operate at many scales, some of which are loosely and others tightly connected, but all are subject to change at different rates and under different conditions. An ecosystem we perceive as stable in a human lifetime may, at a longer scale, be ephemeral, and this realization has profound implications for how we choose to manage, plan, or design for that system (fig. 13.7).

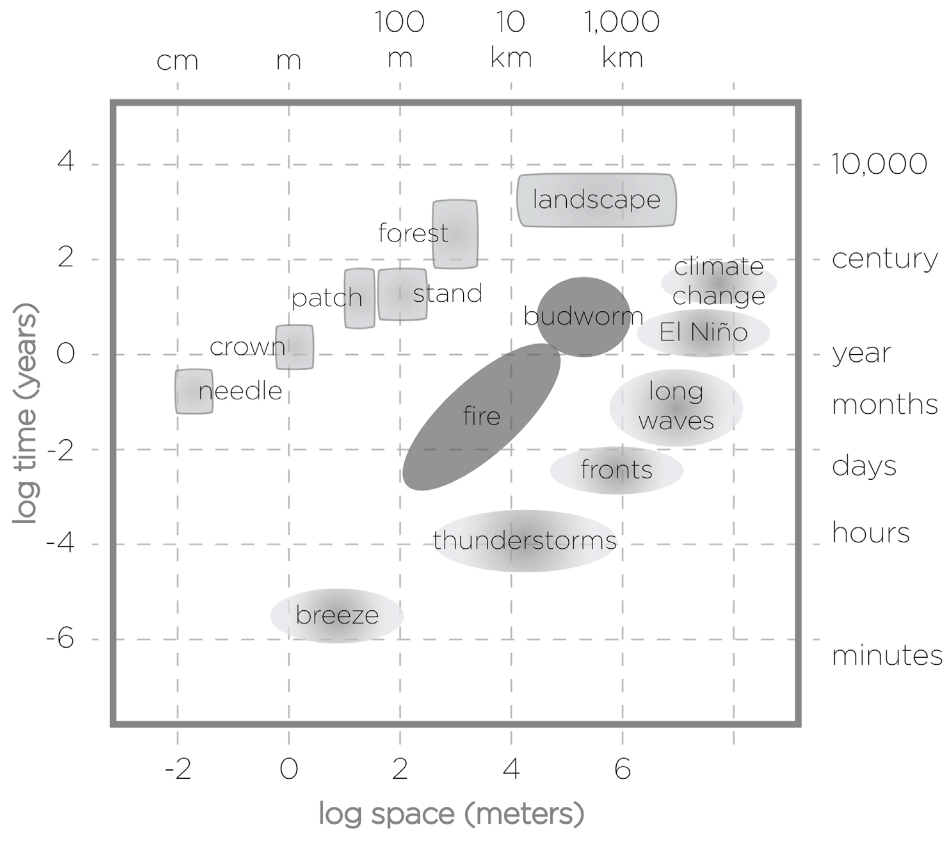


Fig. 13.7. Ecosystem dynamics are observed here across multiple scales of time and space, redrawn by Marta Brocki and adapted from C. S. Holling, "Understanding the Complexity of Economic, Ecological, and Social Systems," *Ecosystems*, Vol. 4, No. 5 (August 2001): 390–405; 393.

There is an important connection among stability, change, and resilience—a property internal to any living system and a function of the unique adaptive cycle of that system. Resilience has both heuristic and empirical dimensions, arising from its origins in psychology, ecology, and engineering. As a heuristic or guiding concept, resilience refers to the *ability* of an ecosystem to withstand and absorb change to prevailing environmental conditions and, following these change-induced events, to return to a recognizable steady state (or a routinely cyclic set of states) in which the system retains most of its structures, functions, and feedbacks. As an empirical construct in engineering, resilience is the *rate* at which an ecosystem (usually at a small scale, with known variables) returns to a known recognizable state, including its structures and functions, following change-induced events. Such events, considered disturbances—which C. S. Holling strategically referred to in the vernacular as "surprises"—are usually part of normal ecosystem dynamics, yet they are also unpredictable, in that they cause sudden disruption to a system.[25] These can include, for example, forest fires, floods, pest outbreaks, and seasonal storm events.

The ability of a system to withstand sudden change at one scale assumes that the behavior of the system remains within a stable regime that contains this steady state in the first place. However, when an ecosystem suddenly shifts from one stable regime to another (in the reorganization phase, via a flip between system states or what is called a "regime shift"), a more specific assessment of ecosystem dynamics is needed. In this context, *ecological resilience* is a measure of the *amount of change* or disruption that is required to move a system from one state to another and, thus, to a different state of being maintained by a different set of functions and structures than the former (figs. 13.8–13.10).[26] Both of these nuanced aspects of resilience are important, because

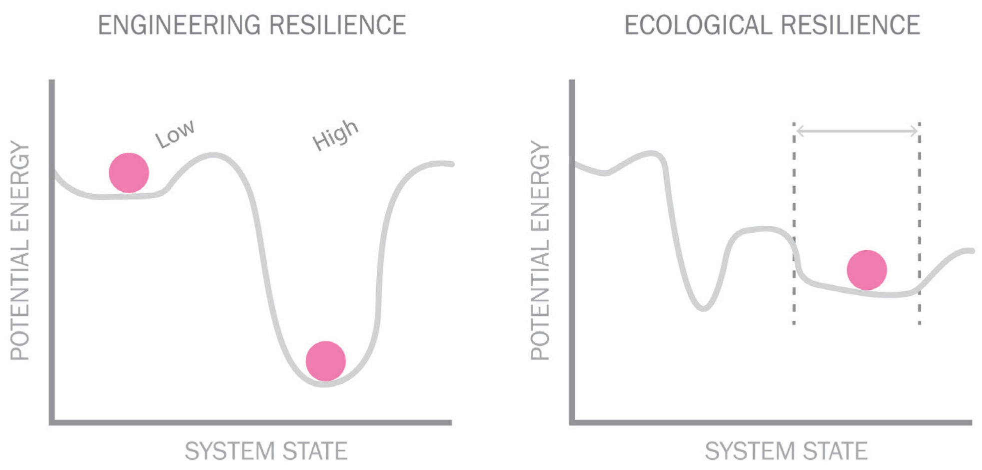


Fig. 13.8. Shown here are two contrasting perspectives on resilience: (left) Engineering Resilience in closed systems (limited uncertainty and known variables) versus (right) Ecological Resilience in open systems (inherent uncertainty and infinite variables). Redrawn by Nina-Marie Lister and Marta Brocki and adapted from Holling, C. S., "Engineering Resilience versus Ecological Resilience," in P. vvC. Schulze, ed., *Engineering within Ecological Constraints* (Washington, D.C.: National Academy Press, 1996), 31–44, 35.

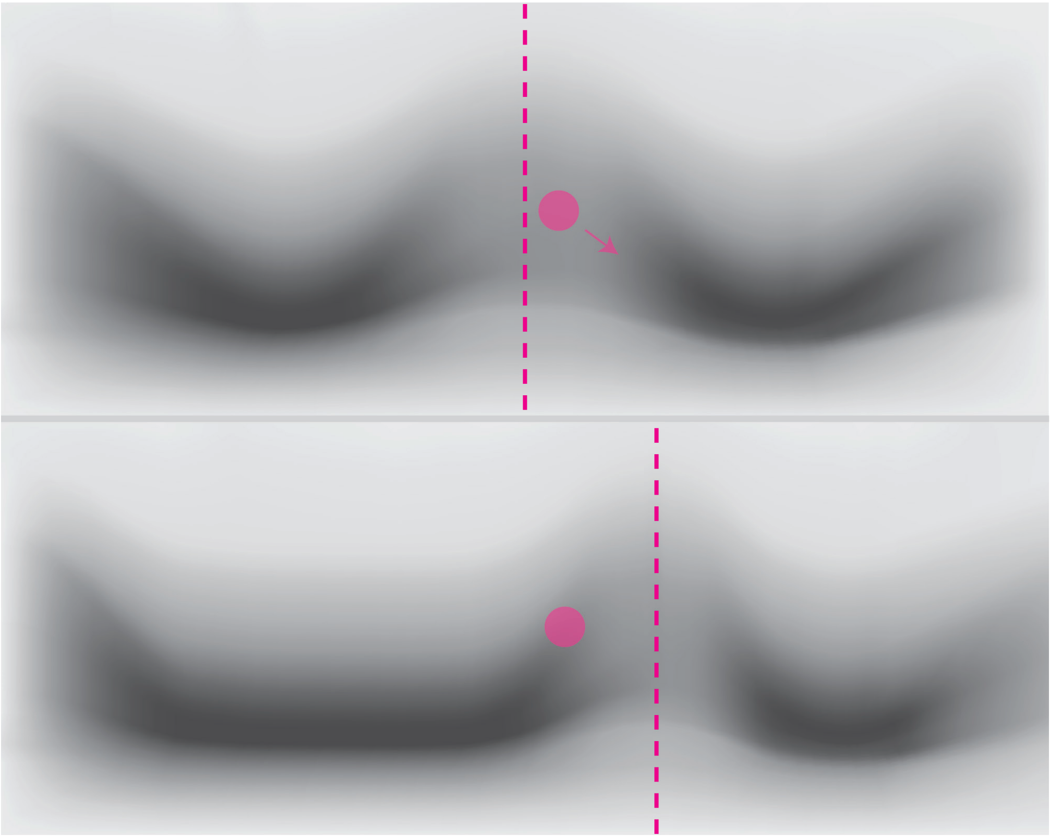


Fig. 13.9. Resilience, seen here as a function of socio-ecological system conditions, is described metaphorically as a (red) ball in a changing basin. The basin represents a set of states that share similar functions, structures, and feedbacks. Though the location of the ball remains the same, changes in the surrounding conditions bring about a shift in state. Redrawn by Marta Brocki and adapted from Brian Walker, C. S. Holling, Stephen R. Carpenter, and Ann Kinzig, "Resilience, Adaptability and Transformability in Social–ecological Systems," *Ecology and Society*, Vol. 9, No. 2 (December 2004): 4; available at http://www.ecologyandsociety.org/vol9/iss2/art5.

they underscore the social-cultural and economic challenges inherent in defining what "normal" conditions are and, in turn, how much change is acceptable at what scale.

It becomes critical to understand the ecological systems in which we live, and, given their inherent uncertainty, to do so through a combination of ways of knowing: experiential, observational, and empirical. Indeed, if there are multiple possible states for any ecosystem, there can be no single "correct" state—only those we choose to encourage or discourage. Notably, these are not questions of science but of social, cultural, economic, and political dimensions—they are also questions of design and planning. The trajectory of research in resilience has been instrumental in exploring the paradoxes inherent within living systems—the tensions between stability and perturbation, constancy and change, predictability and unpredictability—and the implications of these for management, planning, and design of the land. Resilience, in short, as Brian Walker declares, "is largely about learning *how* to change in order not to *be* changed."[27]

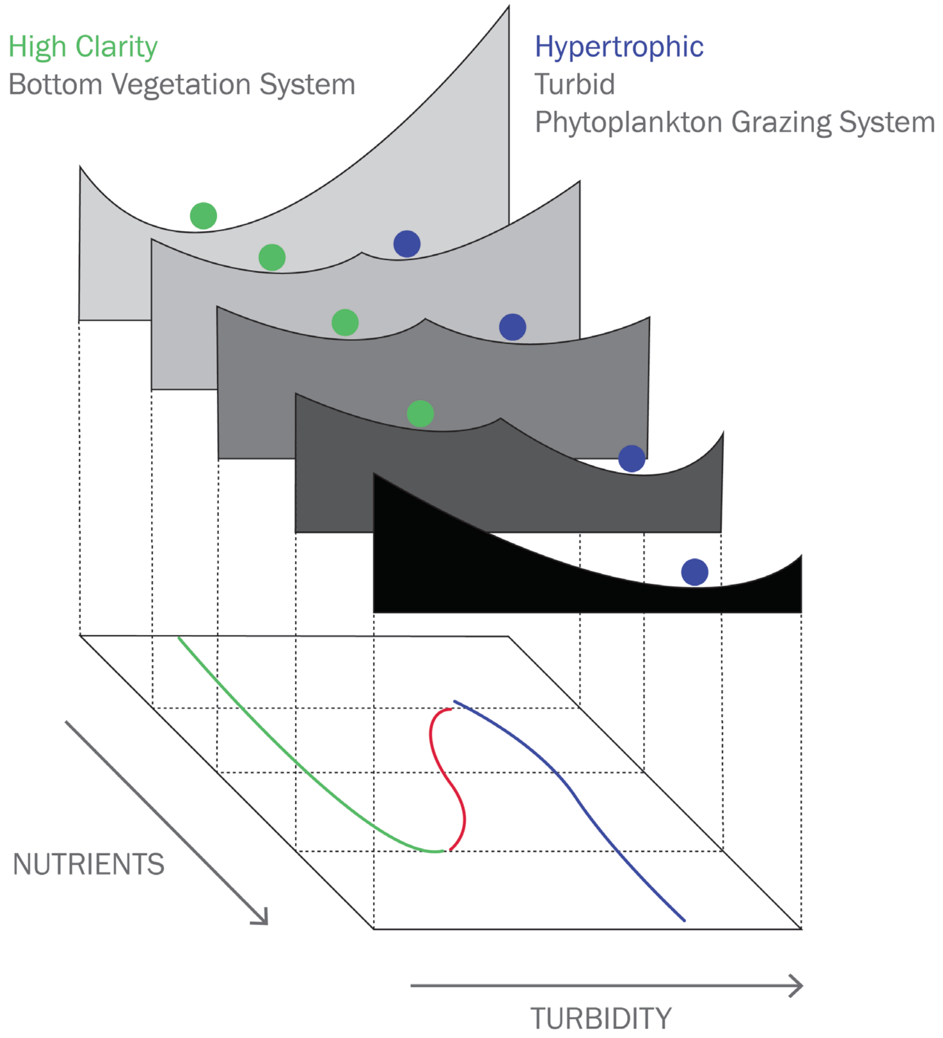


Fig. 13.10. In this early schematic of a complex systems perspective in ecology, we visualize multiple states—all possible—in a freshwater ecosystem. Courtesy of James J. Kay, as sketched in lectures from a course, "Systems Design Engineering," at the University of Waterloo, 1994, in which the author was a student. Redrawn by Marta Brocki and adapted from James J. Kay, and Eric Schneider, "Embracing Complexity: The Challenge of the Ecosystem Approach," *Alternatives Journal*, Vol. 20, No. 3 (July 1994): 32.

From Rhetoric to Tactic: Toward Resilient Design

More recently, applied ecology has been focused on trying to understand what are the ecosystem states that we perceive to be stable; at what scales do they operate; and how are they useful to us. It is important to recognize that stability can be positive or negative, just as change is neither universally good nor bad. Thus, while designers want to encourage a desirable stability (such as access to affordable food or a state of health for a majority of citizens), they also wish

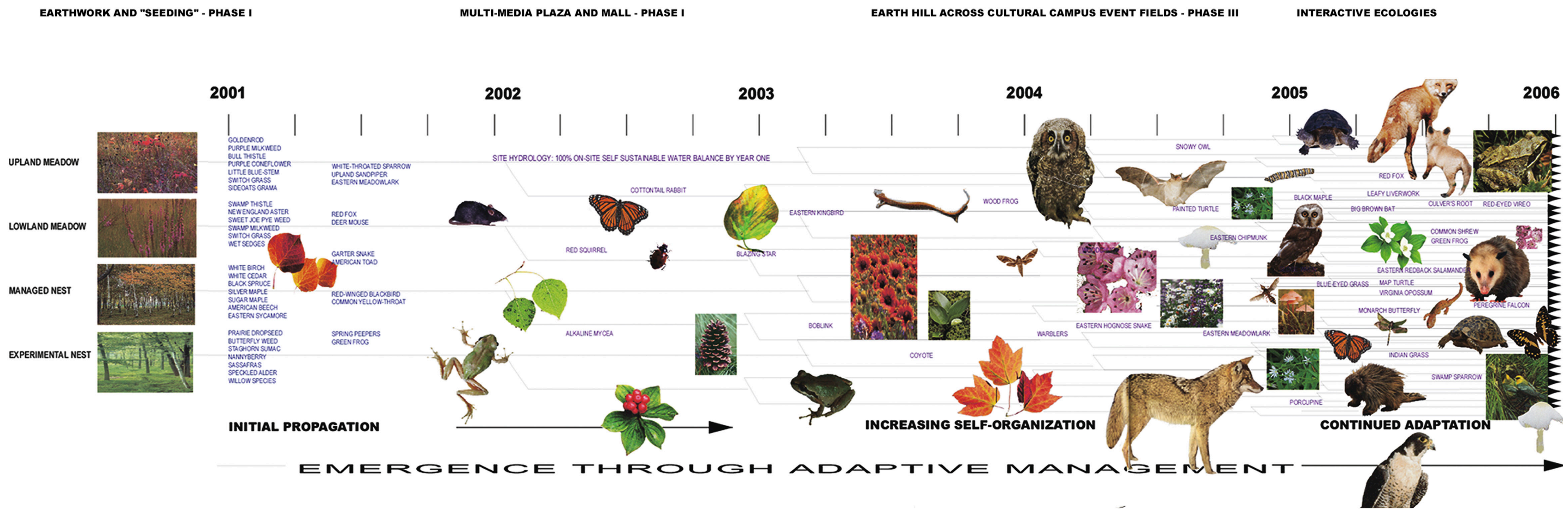


Fig. 13.11. Emergence through adaptive management is in place at Downsview Park in Toronto. The evolution of species composition is shown here from initial propagation through succession and increasing complexity toward self-organization and continued adaptation over time. Drawing courtesy of James Corner/Field Operations and Stan Allen, with Nina-Marie E. Lister, 1999.

to avoid pathological stability (such as chronic unemployment, a state of war, or a dictatorship). This approach has significant implications for management, planning, and design, as it rests on the recognition that humans are not outsiders to any ecosystem but, rather, participants in its unfolding and agents of its design.

In this context, the subscience of urban ecology developed during the 1990s has created a new niche for resilience.[28] Related practices of urban design, environmental planning, and landscape architecture have cross-pollinated in the service of design and planning for healthier cities within which connected vestiges of natural landscapes might thrive. The work of environmental scholars (such as William Cronin, Carolyn Merchant, and David Orr), together with the practice of landscape architects (such as Anne Whiston Spirn, Frederick R. Steiner, and James Corner) effectively brought nature into the embrace of the city, challenging the hierarchical dualism of humans versus nature.[29] The once-discrete concepts of "city" and "country" grew tangled and hybridized, and the boundaries between the urban and the wild blurred (fig. 13.11).

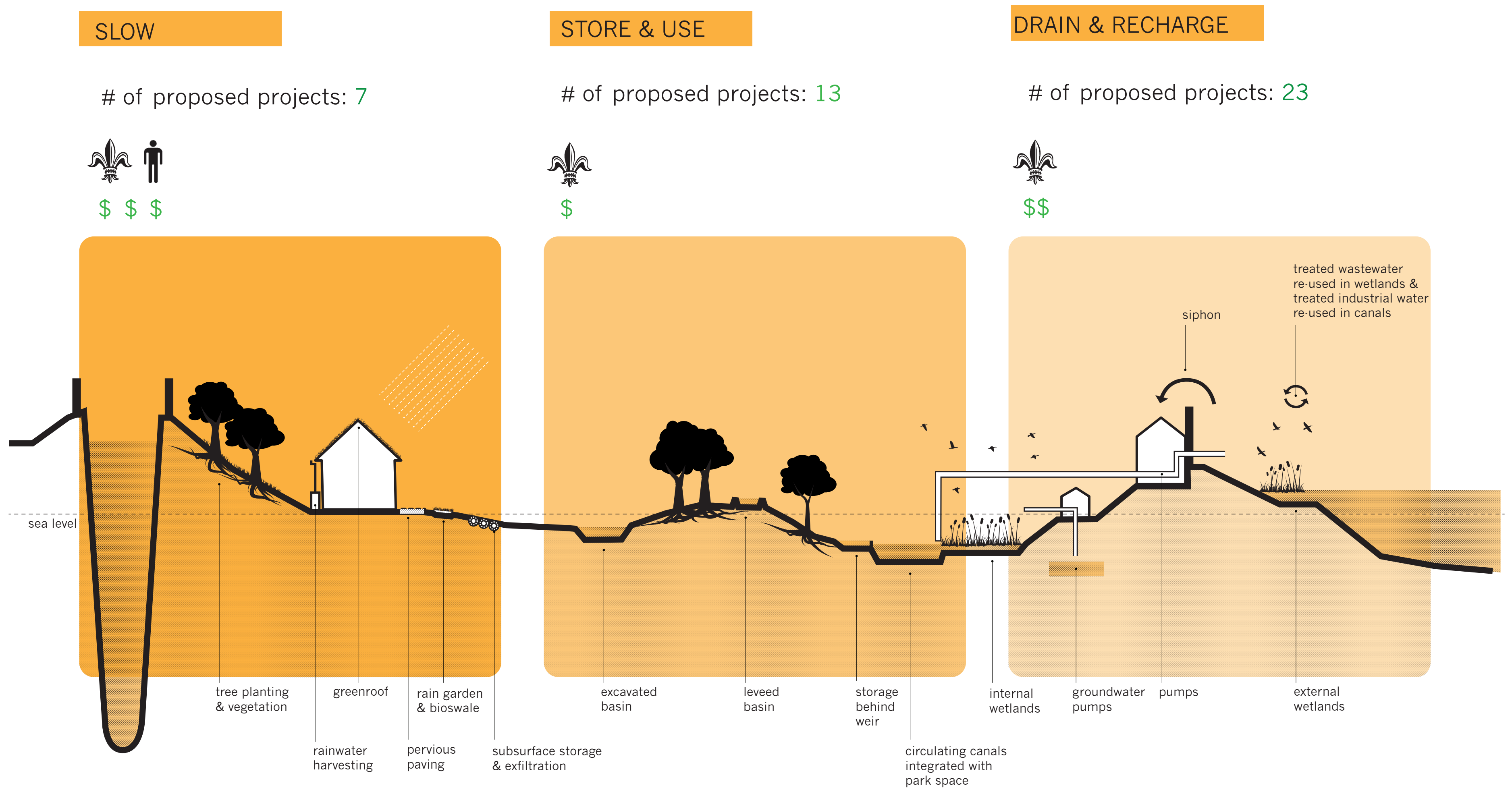
This blurring of boundaries—coupled with the contemporary ecological paradigm of nature as a complex, dynamic open system in which diversity is essential and uncertainty the norm—represented a significant break from ecological determinism and its slavish pursuit of

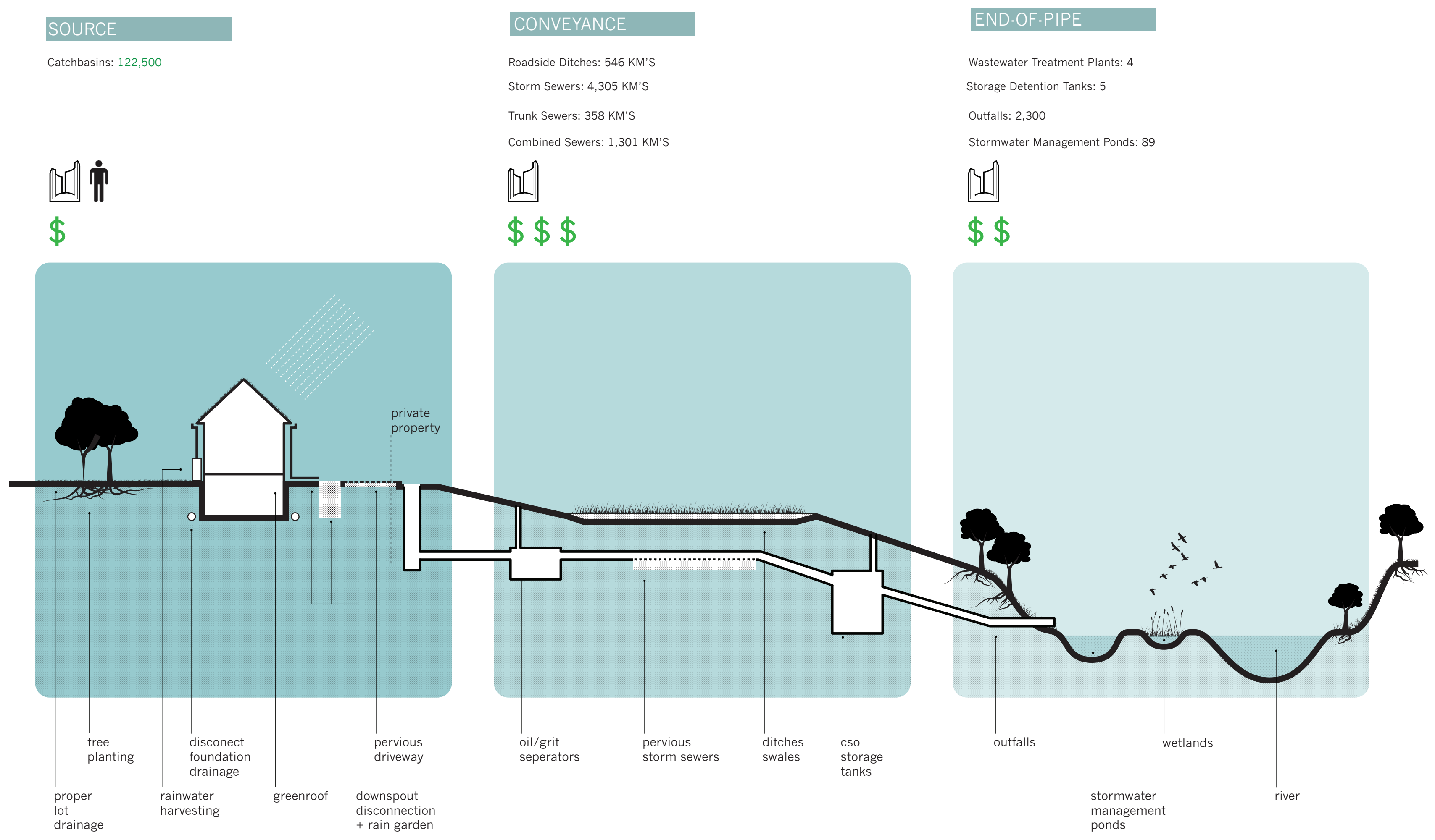
Fig. 13.12. *The Greater New Orleans Urban Water Plan* (2010) proposed a water-management strategy, as drawn in sections here, to depict implications on the landscape's infrastructures. Diagram courtesy of T. Bishop, S. MacLean, R. Felix, V. Manica, A. Linney, and K. Strang, students of Landscape Studio II, University of Toronto, 2014.

perpetual stability underpinned by the illusion of the balance of nature.[30] The increasing hybridization of cultural and natural ecologies has created a powerful aperture for the development of resilience in thought and practice—and with it a new realm for design developed formatively through the interdisciplinary study of socio-ecological systems science, in which coupled systems of humans *within* nature are the norm.[31]

What does design for resilience look like? What tactics do planners and designers need to engage in to attain resilience? To activate such a model for design, one can summarize key principles of adaptive complex systems, generally, and of resilience, specifically.[32] First, change can be slow and fast, at multiple scales. This means that it is essential to look beyond one scale in both space and time and to use various tools to understand the ecological system. Slow variables are, arguably, more important to understand than fast ones, as they provide necessary stability from which to study change at a distance, safely. Yet there can be no universal point of access or ideal vantage point. Mapping, describing, and analyzing the system from multiple perspectives, using different ways of knowing and with a diversity of tools, is critical. If uncertainty is irreducible and predictability is limited, then the role of the traditional expert is also limited—and the role of designer is more akin to that of a facilitator or curator (figs. 13.12 and 13.13).

Fig. 13.13. Toronto's *Wet Weather Flow Master Plan* (2003), proposed improvements in surface water and groundwater, as drawn in sections to depict implications on the landscape's infrastructures. Courtesy of T. Bishop, et al., students of Landscape Studio II, University of Toronto, 2014.





Second, some connectedness, or modularity, across scales is important, and feedback loops should be both tight and loose. Resilient systems are not so tightly coupled that they cannot survive a shock throughout the system that moves rapidly and destructively. For example, children need some limited exposure to viruses to develop immunities but at not too large a scale of impact so as to endanger long-term health. In the same way, design and planning strategies for resilience must consider novelty and redundancy in terms of structures and functions. A useful example is a trail system in a park, which is somewhat connected using a hierarchy of paths that is legible and efficient and yet not so tightly connected that it compromises habitat, folds in on itself, or prohibits spontaneous exploration.

Third, even as there are multiple states in which an ecosystem can function, there is no single correct state. It is important to determine where, in the adaptive cycle, the system of interest is, such that decision makers along with planners and designers can learn patterns and anticipate change (if not predict it). Eventually, perceived stability in any phase will end, and the system will move to a new phase in its adaptive cycle. A nonlinear approach to design that encompasses oscillating or changing states within various phases of a system's development will help facilitate change. For example, it may be desirable to design and plan for seasonally flooded landscapes or along a gradient of water that changes rapidly in a short period of time (figs. 13.14 and 13.15).

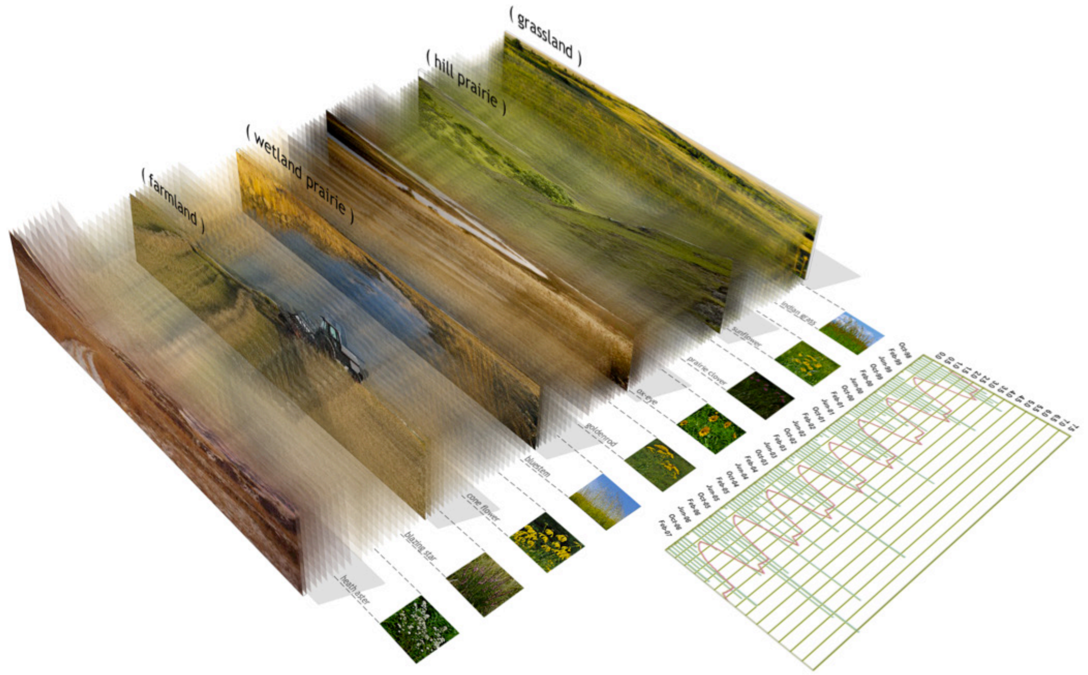


Fig. 13.14. Dynamic change exists in milkweed habitats, as shown in this drawing by Christopher Tuccio (2008). Reproduced from Chris Reed and Nina-Marie E. Lister, eds., *Projective Ecologies* (Cambridge, MA: Harvard University Graduate School of Design, and New York, NY: Actar Publishers, 2014), 281.

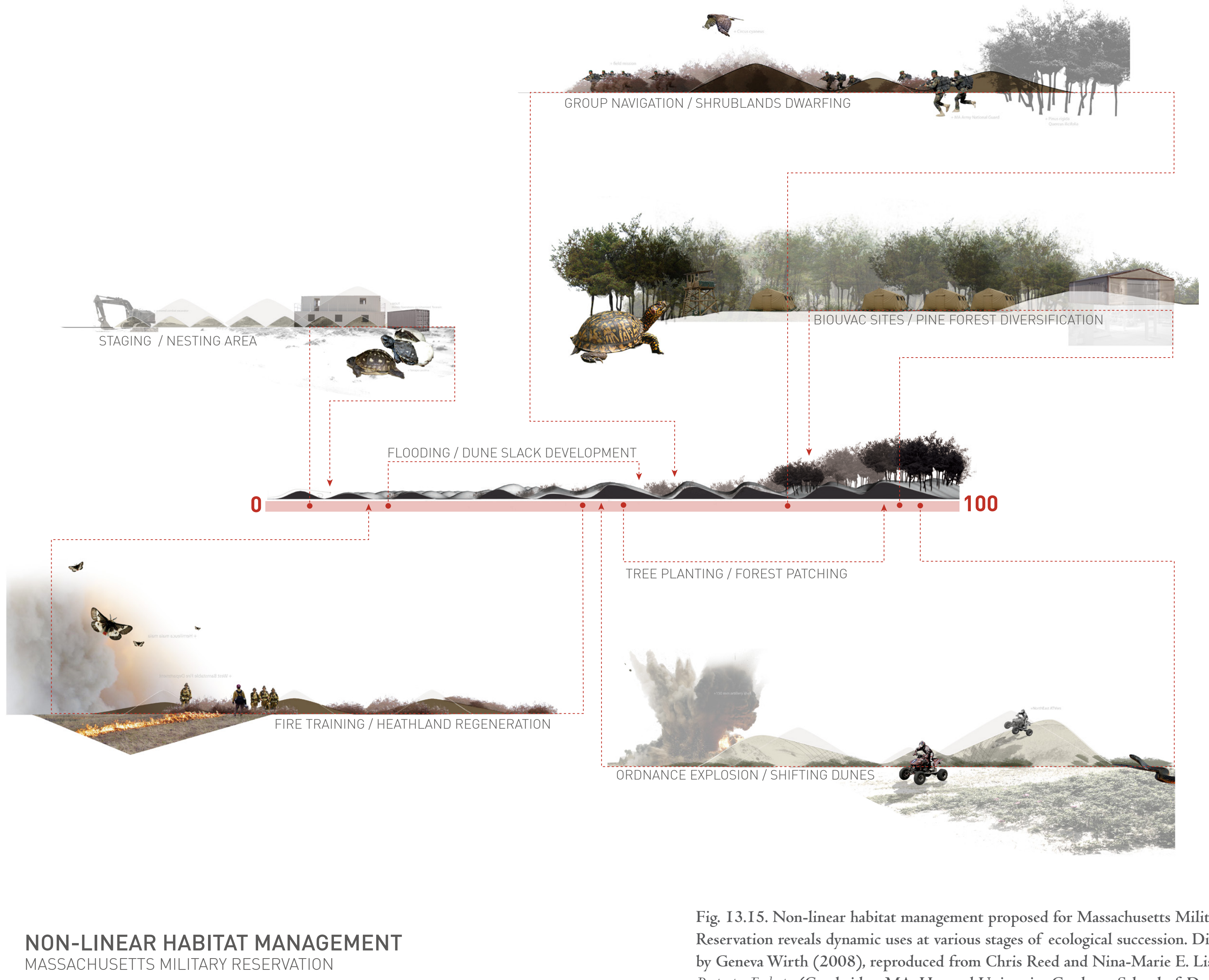
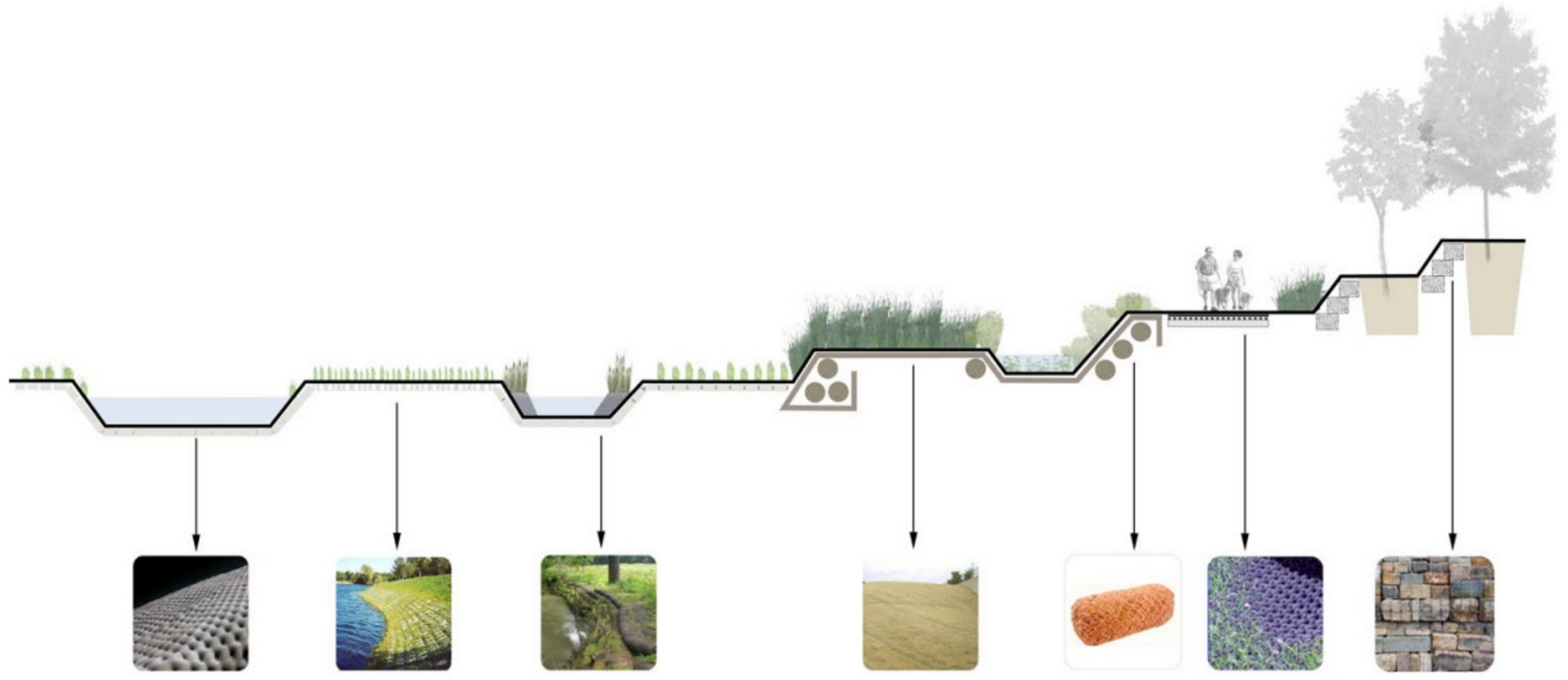


Fig. 13.15. Non-linear habitat management proposed for Massachusetts Military Reservation reveals dynamic uses at various stages of ecological succession. Diagram by Geneva Wirth (2008), reproduced from Chris Reed and Nina-Marie E. Lister, eds., *Projective Ecologies* (Cambridge, MA: Harvard University Graduate School of Design, and New York, NY: Actar Publishers, 2014), 358.

Finally, resilient systems are defined by diversity as well as inherent but irreducible uncertainty. Successful strategies for resilient design should use a diversity of tactics through in-situ experimental and ecologically responsive approaches that are safe-to-fail, while avoiding those erroneously assumed to be fail-safe.[33] This distinction is important, for conventional engineering relies on prediction and certainty to assume an idealized condition of fail-safe design. Yet this is impossible under dynamic conditions of ecological and social complexity, in which predictability is limited at best to one scale of focus. Even knowing one scale exhaustively and managing for it specifically and exclusively may compromise a system's overall function and resilience. The reductionist caveat of "scaling up," using knowledge gained at one scale and applying it to the whole system, cannot work in complex systems, in which scales are nested. Design and planning strategies that support and facilitate resilience should, for example, model its attributes, using living infrastructures that mimic ecological structures and their functions, and design them to be tested and monitored, from which learning and adaptation to changing conditions are built into the design. When design experiments fail, they should fail safely, at a scale small enough not to compromise long-term health (figs. 13.16 and 13.17).

These and other emerging approaches to design for resilience tend to reflect the characteristics of the theoretical shifts that have laid its foundation. They are often interdisciplinary, integrating architecture, engineering, and ecology, specifically, and art and science, broadly. They cross-pollinate freely across scales and hybridize in surprisingly novel ways. The growing use



Figs. 13.16 and 13.17. The proposed master plan for Lower Don Lands in Toronto accommodates the Don River's outflow into Lake Ontario via a flood-friendly landscape of river spits. Diagram and photograph courtesy of Stoss/Landscape Urbanism, 2007.

of living "blue" and "green" infrastructures to soften sea walls, anchor soils, provide rooftop habitats, clean stormwater, soak and hold floodwater, and move animals safely across highways is a collective and optimistic testament to the emergence of a new breed of landscape designers and planners whose creative work mimics, models, and manifests the living systems that inspire and sustain us (figs. 13.18–13.24). Yet activating resilience requires a subtle and careful approach to design and planning: one that is contextual, legible, nuanced, and responsive, one that is small in scale but large in cumulative impact. In designing and planning for change with this sensibility, we have begun to cultivate a culture of resilience and the adaptive, transformative capacity for long-term sustainability—thriving beyond merely surviving—with change in the landscapes we share.

TOP LEFT

Fig. 13.18. Toronto's green and blue infrastructure is seen in the living landscape of the Don River Valley and Evergreen Brick Works, a global center for green cities on a 42-acre (17-hectare) postindustrial site in downtown Toronto, Canada's largest city. Photograph by Toronto and Region Conservation Authority and courtesy of Evergreen Brick Works, 2013.

TOP RIGHT

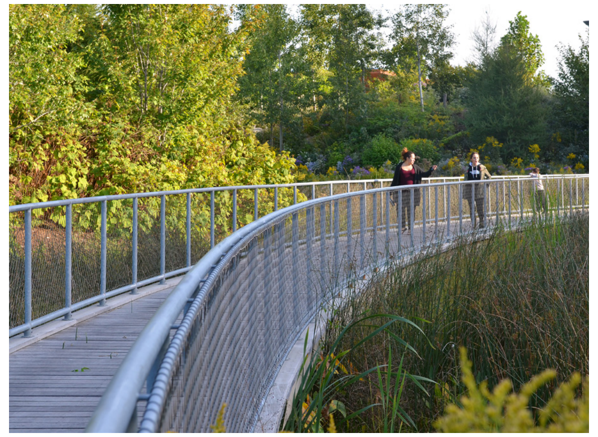
Fig. 13.19. Corktown Common, adjacent to Toronto's Don River, is a flood-friendly landscape with a wetland, designed by Michael Van Valkenburgh and Associates, that allows infiltration and water-holding. Photograph courtesy of Nicola Betts, 2015.

MIDDLE LEFT AND RIGHT, BOTTOM LEFT

Figs. 13.20–13.22. Sherbourne Common—a stormwater filtration and treatment park with water art on the Lake Ontario waterfront in Toronto—is an example of blue and green adaptable infrastructure designed to make the changing water conditions legible. Photographs courtesy of Waterfront Toronto, 2011.

BOTTOM RIGHT

Fig. 13.23. This design for a wildlife overpass offers a new approach for addressing habitat fragmentation by combining a flexible structure and adaptable approach to landscape management. The design emphasizes minimal disturbance on the site and easy creation, assembly, and deployment that can be expanded or adapted as migration pressures change. Diagram courtesy of HNTB Corporation and Michael Van Valkenburgh and Associates, 2010.



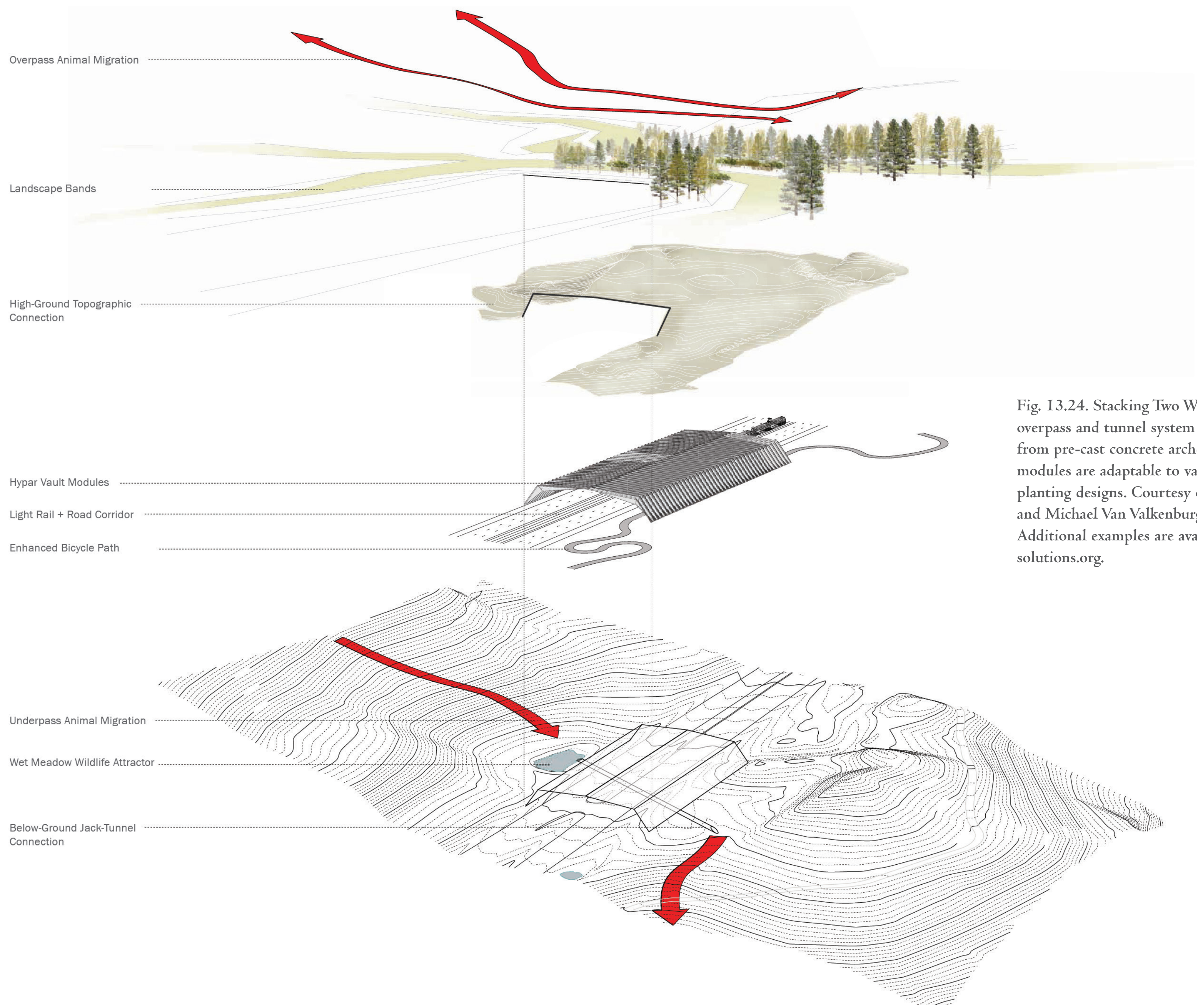


Fig. 13.24. Stacking Two Worlds: Here, an integrated overpass and tunnel system for large mammals is made from pre-cast concrete arches. The hinged, hypar-vault modules are adaptable to various site conditions and planting designs. Courtesy of HNTB Corporation and Michael Van Valkenburgh and Associates, 2010. Additional examples are available at http://www.arc-solutions.org.