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Industrial Ecology as Ecological Design: Opportunities for Re(dis)covery

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Industrial ecology is an evolving field, tied closely to scientific and technological understanding and to changing economic conditions. At the same time, it is a field in tension, held between application goals concerned principally with either economic efficiency or long-term sustainability - but rarely both. Indeed, these goals may inevitably prove mutually exclusive, particularly when considered in light of recent ecological insights and the implications of these insights for decision making in the broadest sense of human/environment interactions.

Furthermore, industrial ecology to date has been typically associated with materials and processes in the context of manufacturing, yet there are many related applications (and their associated fields of study) at broader scales and in wider contexts. Industrial ecology might well be at once informed by and contribute to the advancement of these fields and their more innovative applications. These include, for example, product design, building architecture, and site, urban, and landscape planning, among others. When applied outside the utilitarian envelope of manufacturing, ecological processes may be used both tangibly and symbolically to connect a human-designed built form to its ecological context, effectively forming an organic link between the domains of culture and nature. Indeed, as Dale (2001) has argued passionately, the reconciliation of these domains is essential for meaningful sustainable development. In this sense, and in the spirit of exploring connections for this chapter, I suggest broader societal context(s) for industrial ecology, in which it can be situated comfortably within a simultaneously evolving discipline called ecological design.

Ecological design is an emerging interdisciplinary field of study and practice; it is one of several possible extensions of industrial ecology, beyond the more immediate or localized manufacturing and process-oriented applications. In fact, many would argue that it is a transdisciplinary field, concerned with the creation of entirely new applications that may emerge from its progenitor disciplines or arise from a synthesis of several. Influenced principally by ecology, the environmental sciences, environmental planning, architecture, and landscape studies, ecological design is one of several rapidly evolving (theoretical and practical) approaches to more sustainable, humane, and environmentally responsible development. As such, it may also be considered a critical approach to navigating the interface between culture and nature. In the broadest sense, ecological design emerges from the interdependent and dynamic relationship between ecology and decision making. Van der Ryn and Cowan (1996) described ecological design as a hinge that connects culture and nature, allowing humans to adapt and integrate nature's processes with human creations. In modern industrialized societies, human culture and nature are perceived and treated as separate realms, yet their interface offers fertile ground for the creation of new, hybridized natural/cultural ecologies and the rehabilitation and re(dis)covery of others. Ecological design is inspired by the nexus of these worlds and the urgent need to blur the boundary between them; it seizes on the creative tensions between them and, as such, may offer opportunities for and insights to a re(dis)covered place of "living lightly" with the land.

Thus, ecological design is a necessary and vital context for industrial ecology within the framework of sustainable development originally postulated by Ann Dale (2001) and variously interpreted by Stuart Hill, John Robinson, Raymond Cote and Heinz Peter Wallner, and others in this volume. Three characteristics of ecological design may offer insights and opportunities for industrial ecology for sustainable development. First, I highlight new understandings from systems ecology that essentially amount to a (re)conceptualization of ecology and its processes, the result of which demands an adaptive approach to design. Second, I explore the notion of adaptive ecological design, characterizing it as flexible, integrative, resilient, and responsive in approach, and I consider what this means for industrial ecology. Third, I consider that such an approach to design is also, necessarily, a process for engaging the social dimension, and as such may foster the re(dis)covery of the cultural/natural interface - a critical imperative emphasized by Dale (2001) in her framework for sustainable development, and echoed by Robert Gibson and Steven Peck in Chapter 8 in their call for a full set of relations between humans and nature. Ultimately then, ecological design may be useful, both as a heuristic and as a tool, in helping us create functional versions of Raymond Cote and Heinz Peter Wallner's "islands of sustainability" (Chapter 7). I conclude this chapter with the speculation that, if characterized as part of the ecological design paradigm sketched here, industrial ecology may yet transcend its current internal tension to become an agent of the personal and societal transformative changes called for by Stuart Hill in Chapter 3.

The Ecological Analogue: A Broader Context for Industrial Ecology

How is ecological design a relevant context for industrial ecology when its role in sustainable development is considered? The contributors to this volume explicitly or implicitly allude to the field as being in flux, transition, or a state of tension, and many note the emphasis on materials science and ecological processes. This context is one shared by ecological designers, although usually working at broader scales and in a wider range of applications beyond manufacturing. Indeed, ecological design is often a term associated by implication with landscape-level applications, although it can be just as legitimately applied to product design. This may be because most of the authors who have pioneered the writing in this young field tend to be landscape architects, environmental planners, and systems ecologists (see, for example, McHarg 1969; Lyle 1999; Van der Ryn and Cowan 1996). More often than not, ecological design is invoked as a means to model nature's processes and functions, and therefore as a surrogate model for sustainability (Benyus 1997; McHarg 1998a, 1969; Orr 1992). In this sense, too, industrial ecology has been associated with "modelling nature," often at the risk of ecological myopia. Yet there is a far richer, deeper interpretation to both fields of study and practice, and that is one of the human interpretation of nature (and ecological processes). In essence, nature is an analogue for design, and through such inspired design, a metaphor for human learning. What this implies is room for a more creative design practice allowing for synthesis with human culture, aesthetics, and ingenuity.

To date, however, ecological design has been principally concerned with the realistic emulation of ecological form, function, and, where possible, process. As an outgrowth of, and to some degree, a fusion between landscape architecture, ecology, environmental planning, and the building-science aspects of architecture, there is a distinctive functional emphasis in the discipline (see, for example, Archibugi 1997; Beatley 2000; Edwards 1998; Honachefsky 1999; Platt et al. 1994; Steiner 1991; Stitt 1999). Ironically, artistic elements and visual aesthetics have not been a priority in a discipline that bears the label of "design." I would attribute this principally to the dominance of landscape architecture in influencing ecological design, itself (until recently) a discipline characterized by a schism between garden design and horticulture in one domain, and technical ecologists concerned with ecological restoration and reconstruction in the other. This remediative, reactive "applied ecology" practice of landscape architecture along with related environmental professions have understandably been the progenitors of the new discipline of ecological design, largely (and understandably) as a response to global environmental crises. This is evident in the works of McHarg (1969), Hough (1995), Lyle (1985,1999), and others who emphasize that good design should follow the dictates of nature's form and process, often at the expense of human creativity and originality. As the discipline evolves, and as its practitioners seek to define their roles through various disciplinary lenses, several are beginning to argue fervently for a "new creative space" for the practice. There is a growing collective voice calling for reconciliation of falsely polarized, competing aspects of art and science, culture and nature. (See, for example, Mozingo 1997; Corner 1997, 1999; Mann 2000; Howett 1998; Merchant 1998.)

This phenomenon is parallel to the tensions seen within industrial ecology. Yet it would seem that much of this tension can be traced to the evolution of ecology as the common root discipline of both ecological design and industrial ecology. Despite significant new understandings in ecology over the past fifteen years, as a discipline it is still largely characterized by its own deep schism. This exists in practice and in theory, and is well substantiated in the ecological literature, for example, between species and population-scale studies, and whole-system studies such as ecosystem energetics - a polarization that might be more generally recognized as one of reductionism and holism (explored in detail in Lister 1998). Still, the dominant interpretation and application of modern ecological science is reductionist: decision makers routinely invoke science-based "environmental management," based fundamentally on the notion that nature can be counted, measured, and taken apart, a mechanical entity not unlike Newton's now-outdated notion of the clockwork universe. By extension, conventional (practical) wisdom says that nature can be predicted and controlled, and therefore managed. But what of the newer insights from systems ecology? What have these to do with design?

A Systems Perspective: New Understandings from Systems Ecology

Until recently, most ecologists believed that ecosystems follow a linear path of development toward a particular, biologically diverse, and stable "climax" state. Within the past fifteen years, however, research has shown this view to be incomplete (see, for example, Gunderson and Holling 2002; Holling 1986; Holling and Meffe 1996; Holling et al. 1995; Kay 1991; Kay and Schneider 1994). While ecosystems do generally develop from simple to more diverse, complex states, they develop along any of many possible paths and states, or even flip suddenly into entirely new states. In short, ecosystems are self-organizing, open, holistic, cyclic, and dynamic systems, marked by often sudden, unpredictable change. Diversity, complexity, and uncertainty are normal, and we cannot predict exactly how or when ecosystems will change.

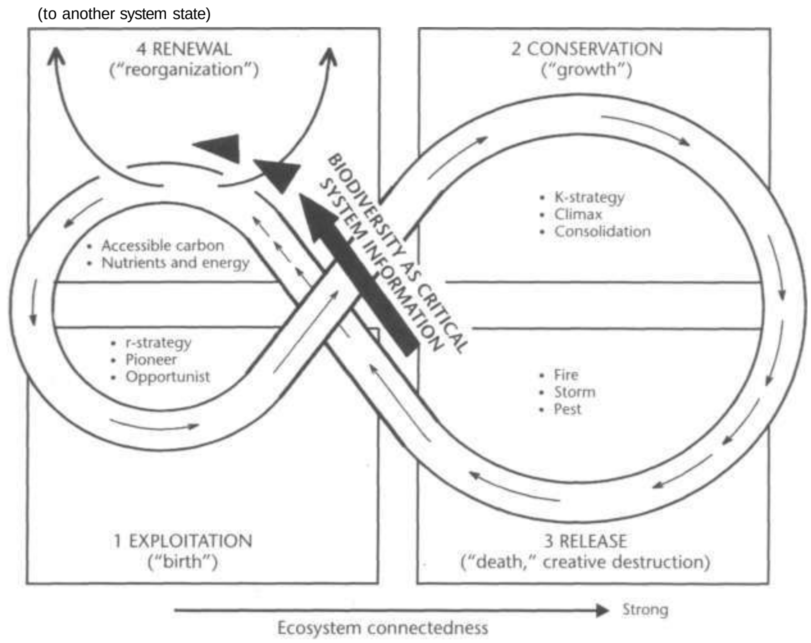
It has long been assumed that there is an inherent balance or stability in nature that biological diversity helps to maintain. This notion of stability is difficult to defend in scientific terms, however. Merely defining what is meant by "stability" is difficult, as living systems experience many fluctuations, such as in the weather, populations, biomass, and so on. More recent ecological ideas, based in part on complex systems science, provide a revised perspective of nature and its living systems, in which the idea of a single "stable" state is replaced with that of a "shifting steady state mosaic" (Holling 1986; Holling and Meffe 1996; Gunderson and Holling 2002). In a forest, for example, there are different patches or stands, each of which is a different age. Each patch will grow to maturity and then fire, windstorm, pest outbreak, or some other disturbance will cause the trees in the patch to fall over and growth to start again. This process goes on in each patch on the landscape, so that at any given moment some part of the landscape will be at any specific age. Which pieces are at which age changes with time. Hence the patchwork mosaic is shifting constantly over the landscape, even though the landscape remains a forest (Bormann and Likens 1979).

Ecosystems actually have multiple possible operating states, and may shift or diverge suddenly from any one of them. For example, in a closed soft maple swamp within a wetland community, changing flows of water can radically alter this state. Drying events such as an extended drought could force its relatively rapid evolution to an upland forest community or grassland. If, in contrast, extended periods of flooding cause high water levels, it would likely become a marsh ecosystem. Red maple *(Acer rubrum)* and silver maple *(Acer saccharum)* will tolerate floods lasting as long as 30-40 percent of the growing season; longer than this and the trees will die, giving way to more water-tolerant herbaceous marsh vegetation (Lister and Kay 2000). The feedback mechanism that maintains the swamp state is evapotranspiration (i.e., water pumping) by the trees. Too much water overwhelms the pumping capability of the trees and not enough shuts it down. The point is that the current state of the ecosystem is a function of its physical environment coupled with the accidents of its history and the uniqueness of its local context. Each of these three ecosystem states is as ecologically healthy and appropriate as the others, and, perhaps more important from a design, planning, or management perspective, there is no single "right" community for this landscape.

Ecosystems may also literally flip into a new state, and do so suddenly. Such flips, properly called bifurcations, have been identified in the Great Lakes, where the dominant ecosystem moves from a benthic to a pelagic state quite suddenly (Kay and Regier 1999; Regier and Kay 2001). Change in an ecosystem as a result of natural catastrophe, such as fire, pest outbreak, or human-induced perturbation, is a normal and usually cyclic event (Holling 1986). The implication is that the ability of ecosystems to recover, reorganize, and adapt in the face of regular change, rather than stability, is critical to their survival. It is in this context that biological diversity is vital to ecosystems: biodiversity is the basis of resilience, and as such, the ability of an ecosystem to buffer itself from being pushed into another state, and to

Figure 2.1

Ecosystem dynamics: Holling's modified figure eight



Source: Adapted from Holling 1986; Holling et al. 1995, 63.

regenerate itself following a shift or other disturbance. Biodiversity could be considered as analogous to a library of information (some recorded long ago, and some only now being written) that provides not only a wide range of possible pathways for the future development of life, but the library of learned repertoires for responding to environmental change and disturbance (Lister 1998).

Figure 2.1 depicts a modified version of Holling's dynamic cycle of ecosystem development, which is a key foundation of the systems view of ecology. Living systems evolve discontinuously and intermittently. Following a sudden disturbance, an ecosystem reorganizes to renew itself or regenerate to a similar or perhaps different state. Immediately after a disturbance, biodiversity at many scales is critical: the abundance, distribution, and diversity of an ecosystem's structures (such as species) and functions (such as nutrient cycling) determine its ability to regenerate and reorganize itself, and its future pathway (Holling et al. 1995). Biodiversity is vital to the normal, healthy functioning of ecosystems because the information it contains and the functions it serves constitute the key elements that determine how an ecosystem will self-organize. In effect, biodiversity forms the palette of future possibilities for an ecosystem (Lister 1998).

However significant, the fact is that these ecological systems-based insights are not yet reflected in ecological design, or in the related applications of environmental management, policy, and planning, or in decision making generally (Lister and Kay 2000). Most design, planning, and management is based on the assumption that more knowledge leads to certainty, and therefore predictability and the success of the design or plan. While this is certainly true in certain deterministic science and engineering applications (such as mechanical physics and transportation engineering), it is not the case with complex living systems. Given the recent understandings from research in ecosystem complexity and dynamics, it is clear that we cannot predict how ecosystems will evolve, change, and behave, because they are complex systems and, as such, are inherently unpredictable. Of course, this does not mean we should fall into the trap of postmodern nihilism and give up trying to design, plan, and manage entirely. Rather, the implication is that we must accept and embrace change as a normal part of life and, through our designs and plans, adapt to it in a more flexible and responsive manner (Kay and Schneider 1994; Lister 1998; Lister and Kay 2000). In sum, this means that to design in an ecological sensibility is to design adaptively. It implies a need to accommodate change, evolution, and the unfolding of landscape, for if change is unpredictable and uncertainty the norm, then design demands creative interpretation of what nature means.

Beyond Ecological Determinism: Adaptive Design for Emergent Complexity

This recent view of ecosystems, and of nature more generally, as open, self-organizing, holistic, dynamic, complex, and uncertain (that is, inherently unpredictable) has significant implications for ecological design and, by extension, for other applications in planning and management, as articulated by Nik Luka in Chapter 5. The essence of the newer understandings of systems ecology is that we can never determine with precision the consequences of our actions. In effect, the current and widely accepted concept of "environmental management" is really an oxymoron, because we can never truly "manage" living systems (Kay and Schneider 1994). What we can do, however, is refocus our energies on those human activities that provide the context for the self-organizing processes in ecosystems. This implies a profound change in environmental decision making, from planning and design to management.

If uncertainty and regular change are inevitable, then we must learn to be flexible and adaptable in the face of changes. Although there is a small but growing literature on what has been called "adaptive management" (see, for example, Holling 1986; Lee 1993; Walters 1986; Walters and Holling 1990; Lister and Kay 2000), there is little understanding of what this means in practice. Given the importance of multiple perspectives at various ecosystem scales (essentially a systems approach), one of the first steps toward flexible, adaptive, and responsive design, planning, or management is to use a diversity of approaches (Grumbine 1997). In general, this means emphasizing the small-scale, the experimental, and the action-oriented. Because ecosystems may change in any number of possible ways, there may be an infinite number of possibilities for design (and ultimately management). "Good" ecological design, then, requires a diversity of tools, techniques, and methods. More important perhaps, learning becomes a central goal, leading ideally to continual improvement in design, planning, and management - in effect, to long-term adaptation.

In ecological design generally and in industrial design more specifically, we might consider demonstration projects that emphasize "learning-by-doing" (Lee 1993). Such projects should be small enough that if they are not successful, they can fail safely, without endangering an entire community, ecosystem, watershed, or habitat. "Failures" or mistakes may provide experience that can be used in the future. In this way, the "surprising" nature of ecosystems can be turned into a learning opportunity rather than a liability. As Lee (1993, 56) observes, "experiments often bring surprises, but if resource management is recognized to be inherently uncertain, the surprises become opportunities to learn rather than failures to predict."

Of course, good ecological design (and industrial ecology) must still be rooted in rigorous science, some of the best of which is of course reductionist, and draw on new knowledge in biology and ecology, among other related disciplines. But adaptive and responsive design must also proceed on a broader scale, linked to experience as well as to research. Learning through experimentation and action also requires local knowledge for context, as well as field-trained specialists with a broader range of expertise and research. Fundamentally, adaptive design demands a stronger connection between knowledge and action.

"Learning by doing" implies profound changes to our tradition of design, planning, and management. It is still widely assumed that with enough research and knowledge, nature (and ecological systems) can be predicted and therefore controlled. As discussed here, however, new insights from systems ecology and complex systems theory have shown that this is not how the real world really works. If ecosystems are indeed dynamic, diverse, and open to surprise and sudden change, then nature is not under our control, and ecology cannot be realistically or exactly modelled in the predictive sense. Adaptation, responsiveness, and flexibility become essential traits, and humans must again learn to live *with* nature. To do so, we must learn to look to multiple perspectives, a diversity of voices and values, at different scales and in different contexts if we wish to truly manage our interactions within nature - and that surely is within the domain of our control and the basis for good design.

Although there are many ways to emulate the diversity that is essential to living systems in our own human systems of design, planning, and management, we do not typically do so. Rather than including a diversity of expertise, voices, and professions on our design teams, for example, we tend to favour design and planning processes, as well as management structures, that are rigid, homogeneous, and static. As such, they are the very opposite of nature's model (Lister 1998; Lister and Stevens 2000; Dale 2001).

More perplexing is the fact that ecological design, despite the potent new understandings from systems ecology, continues to emulate an ecologically deterministic model of nature. As the self-proclaimed "father of ecological design" (he claimed to have invented it [1998c]), McHarg's (1969, 1998a, 1998b, 1998c) legacy defines ecological determinism. For example, his oft-cited 1969 work *Design with Nature was* not a suggestion but rather an imperative, a command to follow the lay of the land literally in each design. While it can now be more broadly interpreted in the newer context of adaptive, resilient, flexible, and responsive design, his interpretation of ecological "fitness" for good design meant that the correct (truthful) reading of the landscape would necessarily *prescribe* appropriate design, wherein form and function are indivisible. Furthermore, his imperative has rarely been interpreted as a call for more open, diverse, or flexible planning and design processes, nor does it typically include a diversity of perspectives, voices, or professions participating on design teams. Certainly we can appreciate and understand McHarg's deterministic approach when it is contextualized as appropriate environmentalism during the 1960s. But we should not continue to follow the "Design with Nature" imperative without some critical reflection on what this means today, in the face of the new understandings of ecosystem complexity, uncertainty, and diversity. Well-intentioned but uncritical acceptance of environmental platitudes leaves little room for creative interpretation in the face of change, and even less for meaningful, adaptive, and responsive design.

Design as Process: Engagement and Learning for Re(dis)covery

How, then, do we cope with continuous, dynamic change in our landscapes and ecosystems? How can we design adaptively, being responsive to context and the uniqueness of local conditions? If we can no longer follow McHarg's ecological imperative, for example, certain that "nature will show the way," there must surely be a new and revitalized role for humans as creative agents in the process of unfolding, as interpreters of change, as *designers* once again. After all, what is the role of the designer if not to *design?* Design, as Nik Luka details in Chapter 5, is a process of discovery. It implies intentional shaping, manipulation, and (re)creation. In the urban ecological context, it also means recovery of something that has been lost - an attachment to landscape, to nature's rhythms, to place. Perhaps, as the title of this chapter suggests, ecological design is about both - I would argue that it is a process of re(dis)covery. This process must necessarily be creative, and engaging of local people, collaborating in a learning journey based on continual adaptation. Such a design process may ultimately be what Jantsch (1975) intended when he spoke of design as "planning plus love." Indeed, a similarly inspired and good ecological design process might yet move us toward the reconciliation of imperatives for sustainable development (Dale 2001).

Sustainable development is, of course, about making choices, in light of necessary limits to growth and a compelling need for equity. As an integral component of sustainable development, ecological design incorporates aspects of science, art, culture, and nature. While to some extent ecological realities can be determined through scientific inquiry and learned experience, in a complex world this knowledge illuminates not solutions but choices and trade-offs, the selection of which is driven by values.

Yet much of institutionalized planning - which is the basis for a considerable portion of architectural and landscape design - is rooted in a "scientistic" tradition known as the "rational-comprehensive approach." This approach is modelled on the normal (Kuhnian) scientific method and advocates objective decision making, as suggested by Andrews (cited and explored in Chapter 10). In this narrower and bureaucratic perspective, planning (and by extension, design) is seen as a top-down, expert-driven, rational activity, relying on management through control (Dalton 1986). But as we know through systems-based research, nature and ecological processes cannot be managed through prediction and control. In addition, in its social, cultural, economic, and political dimensions, nature has very much to do with values, and this must be reflected in related design, planning, and management for the natural and human environments. The domains of science and values must therefore be integrated within good ecological design. Such a design process should be one through which we (or affected local people) collectively evaluate and decide which of many futures we wish to steer ourselves toward, through choices, trade-offs, trial and error, learning by doing, and flexible management. The designer's role in such a process becomes one of facilitator, and one that cannot exist in isolation.

Design processes, whether focused on industrial or landscape ecological processes, have the power to act as potent agents of change. In becoming more open, flexible, and receptive to a diversity of perspectives, and adaptive and responsive to local conditions, design processes are potentially powerful vehicles for shared, experiential learning by their participants. In several design exercises that have involved a diversity of professions, a range of experts, and meaningful collaboration with local people, I have seen indicators of what Stuart Hill calls "transformative change" (Chapter 3) among design team members. Personal and collective changes have been documented as emerging from the shared learning experience of "design-in-action/' on the part of both participants and the designers themselves (see, for example, Lister and Kay 2000; Lister and Stevens 2000). These experiences may resonate with Nonita Yap's suggestion (Chapter 6) that there exists the potential for the development of social capital through industrial ecology and related design processes. Social capital is indeed considered an emergent property of learning-based experiences, and is, according to Dale (2001), one of the primordial capitals essential to sustainable development.

As a learning-based process for re(dis)covery, ecological design (and by extension, industrial ecology) should be considered a useful tool to overcome the culture/nature dualism that forms a fundamental barrier to sustainable development (articulated in Dale 2001, and alluded to in Chapters 3 and 14 of this volume). Ecological design indeed holds the potential to, at a minimum, navigate the interface of culture and nature in a way that has not yet been part of modern history. In a more optimistic sensibility, I would suggest that in its range from discipline to process to practice, it may provide the intellectual and psychological space to create entirely new, emergent, or hybridized cultural/natural ecologies. How can it do so? What are the indicators that this emerging "interdiscipline" has the power to at once unify and transcend an age-old dualism polarizing the two dominant forces on earth, culture and nature? First, let us consider for a moment the characteristics of this dualism.

The "modern condition" is founded on the notion that humans are separate, distinct from nature. Whereas nature is raw, disordered, unkempt, and dirty, humans are cultured, refined, clean, ordered, and neat. Whereas nature is a kaleidoscope in motion, a cacophony, humans strive for stability, reject change, and seek permanence. Although the culture/nature dualism has been thoroughly explored in theory by others (see, for example, Merchant 1980), we can see tangible evidence of this dualism every day in the most mundane expression of our urbanized modernity - the manicured lawn. The lawn is anti-ecological design: it is the symbol of modern urban culture, free from leaves, detritus, and decay, and homogeneous in form, colour, and shape; it screams of pristine order, managed perfection. It is the *piece de resistance* of determinism and control (see, for example, Bormann et al. 1993).

Ironically, modern environmentalism echoes this dualism through the sentiment that raw nature, as wilderness, is "pristine," and somehow off limits to marauding humans. For example, Mann (2000, 35) laments: "By finding some putative ecological Golden Age the standard by which contemporary environmental actions can be evaluated, activists avoid the unsettling necessity of relying on human judgement. But the Golden Age is a dream, and nature provides no guide ... Try as we might, we cannot escape from ourselves." Indeed, the doomsday environmentalists frequently warn that the earth needs "saving," when in fact systems ecology suggests that the earth will continue to evolve with or without us. We may be quite simply evolved out of existence if we continue to "push" our ecosystems to a state of relative ill-health for human survival.

So, in large part, the power of ecological design lies in its reconciling potential to harmonize and (re)connect the social, ecological, and economic imperatives for sustainable development (Dale 2001; Robinson and Tinker 1997). To extrapolate further, as a learning process that is adaptive, responsive, resilient, and inclusive, ecological design is also about re(dis)covering, (re)affirming, (re)creating, and (re)considering our place in nature and our landscapes. For example, by reconciling art and science through the process of inspired design, we can create living places that are scientifically feasible and aesthetically pleasing. Of course, as an integrative and creative force, good ecological design must be about both humans and nature equally, in all our dimensions, from art and science to passion and reason. As Mozingo (1997, 58) appropriately observes, "ecological designs do need to appeal to the joyous, the freely given, the heroic. They deserve to be beautiful - to have an aesthetic." In the end, this is a key challenge for ecological design, and by extension, part of the transition to "deep" industrial ecology within the context of sustainable development suggested by other contributors to this volume.

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References

Archibugi, F. 1997. *The ecological city and the city effect: Essays on the urban planning requirements for the sustainable city.* Aldershot, UK: Ashgate.

Beatley, T. 2000. *Green urbanism: Learning from European cities.* Washington, DC: Island Press.

Benyus, J. 1997. *Biomimicry: Innovation inspired by nature.* New York: William Morrow.

Bormann, F.H., D. Balmori, and G.T. Gebelle. 1993. *Redesigning the American lawn: A search for environmental harmony.* New Haven, CT: Yale University Press.

Bormann, F.H., and G.E. Likens. 1979. *Patterns and process in a forested ecosystem.* Berlin: Springer-Verlag.

Corner, J. 1997. Ecology and landscape as agents of creativity. In *Ecological design and planning,* ed. G. Thompson and F. Steiner, 81-108. New York: Wiley.

-. 1999. Recovering landscape as a critical cultural practice. In *Recovering landscape: Essays in contemporary landscape architecture,* ed. J. Corner, 1-26. New York: Princeton Architectural Press.

Dale, A. 2001. *At the edge: Sustainable development in the 21st century.* Vancouver: UBC Press.

Dalton, L.C. 1986. Why the rational model persists: The resistance of professional education and practice to alternative forms of planning. *Journal of Planning Education and Research* 5: 147-53.

Edwards, B., ed. 1998. *Green buildings pay.* London: E&FN Spon.

Grumbine, R.E. 1997. Reflections on "what is ecosystem management?" *Conservation Biology* 11 (1): 41-47.

Gunderson, L.H., and C.S. Holling, eds. 2002. *Panarchy: Understanding transformations in human and natural systems.* Washington, DC: Island Press.

Holling, C.S. 1986. The resilience of terrestrial ecosystems: Local surprise and global change. In *Sustainable development of the biosphere,* ed. W.C. Clark and R.E. Munn, 292-317. Cambridge: Cambridge University Press.

Holling, C.S., and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10: 328-37.

Holling, C.S., D.W. Schindler, B.W. Walker, and J. Roughgarden. 1995. Biodiversity in the functioning of ecosystems: An ecological primer and synthesis. In *Biodiversity loss,* ed. C. Perrings et al., 44-83. Boston: Cambridge University Press.

Honachefsky, W.B. 1999. *Ecologically-based municipal land use planning.* New York: Lewis.

Hough, M. 1995. *Cities and natural processes.* London: Routledge.

Jantsch, E. 1975. *Design for evolution: Self-organization and planning in the life of human systems.* New York: George Braziller.

Kay, J.J. 1991. A non-equilibrium thermodynamic framework for discussing ecosystem integrity. *Environmental Management* 15 (4): 483-95.

Kay, J.J., and H.A. Regier. 1999. An ecosystem approach to Erie's ecology. In *International symposium: The state of Lake Erie (SOLE) past, present, and future. A tribute to Drs. Joe Leach and Henry Regier,* ed. M. Munawar, T. Edsall, and I.F. Munawar, 511-33. Leiden, Netherlands: Backhuys Academic Publishers.

Kay, J.J., and E. Schneider. 1994. Embracing complexity: The challenge of the ecosystem approach. *Alternatives* 20 (3): 32-38.

Lee, K.N. 1993. *Compass and gyroscope: Integrating science and politics for the environment.* Washington, DC: Island Press.

Lister, N.-M. 1998. A systems approach to biodiversity conservation planning. *Environmental Monitoring and Assessment* 49 (2/3): 123-55.

Lister, N.-M., and J.J. Kay. 2000. Celebrating diversity: Adaptive planning and biodiversity conservation. In *Biodiversity in Canada: Ecology, ideas and action,* ed. S. Bocking, 189-218. Toronto: Broadview Press.

Lister, N.-M., and P. Stevens. 2000. Unholy alliances: Building creative partnerships for sustainable developments. *Perspectives* (Journal of the Ontario Association of Architects) 8 (3): 11-15.

Lyle, J.T. 1985. *Regenerative design for sustainable development.* New York: Wiley.

-. 1999. *Design for human ecosystems: Landscape, land use and natural resources.* Washington, DC: Island Press.

McHarg, I. 1969. *Design with nature.* New York: Wiley.

-. 1998a. Ecological determinism. In *To heal the earth: Selected writings of Ian L. McHarg,* ed. I. McHarg and F. Steiner, 39-56. Washington, DC: Island Press.

-. 1998b. Values, process, and form. In *To heal the earth: Selected writings of Ian L. McHarg,* ed. I. McHarg and E Steiner, 57-71. Washington, DC: Island Press.

-. 1998c. Ecology and design. In *To heal the earth: Selected writings of Ian L. McHarg,* ed. I. McHarg and F. Steiner, 194-202. Washington, DC: Island Press.

Mann, C. 2000. Three trees. *Harvard Design Magazine* 10: 31-35.

Merchant, C. 1980. *The death of nature: Women, ecology and the scientific revolution.* New York: HarperCollins.

-. 1998. Partnership with nature. *Landscape Journal* Special Issue (Nature Constructed/ Nature Revealed): 69-71.

Mozingo, L. 1997. The aesthetics of ecological design: Seeing science as culture. *Landscape Journal* 16 (1): 46-59.

Orr, D.W. 1992. *Ecological literacy: Education and the transition to the postmodern world.* Albany, NY: SUNY Press.

Platt, R.H., R.A. Rowntree, and P.C. Muick, eds. 1994. *The ecological city: Preserving and restoring urban biodiversity.* Amherst: University of Massachusetts Press.

Regier, H.A., and J.J. Kay. 2001. Phase shifts or flip-flops in complex systems. In *Monitoring in support of policy: An adaptive ecosystem approach,* vol. 5, *Encyclopedia of global environmental change,* ed. E. Munn, 422-29. London: Wiley.

Robinson, J.B., and J. Tinker. 1997. Reconciling ecological, economic and social imperatives: A new conceptual framework. In *Surviving globalism: Social and environmental dimensions,* ed. T. Schrecker, 71-94. London: Macmillan.

Steiner, F.R. 1991. *The living landscape: An ecological approach to landscape planning.* New York: McGraw-Hill.

Stitt, F.A., ed. 1999. *Ecological design handbook: Sustainable strategies for architecture, land-. scape architecture, interior design, and planning.* New York: McGraw-Hill.

Van der Ryn, S., and S. Cowan. 1996. *Ecological design.* Washington, DC: Island Press.

Walters, C.J. 1986. *Adaptive management of renewable resources.* New York: Macmillan.

Walters, C.J., and C.S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 71 (6): 2060-68.