Faculty of Design

2014

Return to the (managed) wild: Interpreting human settlements as “designer ecosystems”

Ruttonsha, Perin

RETURN TO THE (MANAGED) WILD:

Interpreting Human Settlements as "Designer Ecosystems"

Perin Ruttonsha & Stephen Quilley

Waterloo Institute for Social Innovation and Resilience (WISIR), University of Waterloo

Abstract

Human civilizations stand out, recently, among other biotic communities, as a globally dominant presence — the impact of their activities echoed across terrestrial, marine, and atmospheric systems (Steffen, Crutzen, & McNeill, 2007; Hobbs, Higgs, & Harris, 2009). At the centre of this are human settlements — the magnet for, container to, and expression of human cultural systems. Settlement systems directly interface between the human species and the biosphere, mediating what is an ambiguous nature-culture relationship. If one embraces Lovelock's (1979) Gaia hypothesis, whereby the planet is considered an interdependent, self-regulating unit, then one might view these constructed systems as part of the 'natural order' of things. Simply accepting human activity and its resulting technologies as an extension of a self-organizing, natural world, however, risks absolving the species of environmental accountability (White, 2003). In light of current environmental pressures, the challenge of social-ecological integration is one that requires closer articulation, both philosophically and schematically. While deep ecology (Devall & Sessions, 1985; Naess, 1989) and biosphere consciousness (Rifkin, 2009) inspire holistic thinking rooted in a connection to the natural world, it is unclear what adoption of these kinds of eco-philosophies should mean, on practical terms, for highly engineered, urban systems. No doubt, achieving a state of complete integration with ecosystem processes would entail nothing short of a long-term unwinding of rigid infrastructural and social regimes, through an adaptive, phased, scaled, and multi-stakeholder-engaged process of renewal. The arguments for pursuing this direction as part of a long-range sustainability strategy, and the means by which it might be possible to do so within the current social-technological landscape, are worth examination. Recent to the field of ecology, novel ecosystems discourse (Hobbs, Higgs, & Hall, 2013) provides a frame within which this conversation might unfold. Novel ecosystems research reveals the presence of a certain degree of social-ecological co-evolution over time — in what Hobbs, Higgs, and Harris (2009) refer to as hybrid, novel, or *designer ecosystems* — accordingly, unraveling the myth of nature-culture separation, and positioning the human species as a co-creative agent (Pearce, 2013). This paper examines the potential for the development of social-ecological novelty as a pathway to sustainability in settlements, engendering hybrid models that are both resilient and complex. In pursuit of such an approach, the worlds of designers and ecologists would necessarily converge to conceive of human systems as entrenched in inhabited ecosystems.

Settled Living in the Age of Ecology

Some declare the past half century to be the dawning of an 'age of ecology' (Cayley, 1991; Radkau, 2014); some characterize these same years as the emergence of a biosphere consciousness (Rifkin, 2009); some qualify ecology as a master science through which all other disciplines should be oriented (Homer-Dixon, 2009), or equate ecosystem approaches with concepts of holism (Capra, 2002; Waltner-Toews, Kay, & Lister, 2008). While these positions might be related notionally, they each point to slightly different social phenomena: the first, growth in environmental policy and action; the second, a search for unifying social-cultural experiences through an acknowledgement of connection to biosphere; the third, adoption of ecology as a science of complexity (even if only metaphorically); and, all of these wrapped within a renewed sense of collective responsibility for human action within the shared planetary system (Cayley, 1991). What hovers as a frame of orientation within this age of ecology, waiting to be adopted more broadly as both a philosophical and schematic hook, is a simple, operational metaphor: that of the dynamic network (Capra, 2002).

The dynamic network as an operational archetype prevails across complex systems thinking and ecosystems thinking approaches (Capra, 2002; Waltner-Toews et al., 2008). Relative to sustainability discourse, its advantage as a metaphor or heuristic is that it does not immediately impose value judgments; one might observe the currents within any given system without initially critiquing them. In this way, sustainability thinking combined with ecosystems thinking starts to take on the quality, in the words of Stewart Brand (1999), of a 'continuous game' — the object of which is to keep playing, the means by which this takes place being somewhat flexible. This view renders the world of sustainability planning significantly more colourful, while also extremely fuzzy. If one releases fixed views of a notional utopia, more options for sustainability pathways can enter the frame, and continual change becomes an expected part of the landscape. Of course, this is not to suggest that value judgments can be left out entirely. Questions of *what kind of game is this biotic community playing?*, *who is given agency to steer the ship?,* and *what will continue within this dynamic planetary system*? naturally arise. Presumably there is an overriding desire to maintain biotic life, inclusive of human life, over the long term. Whether the human constituency as a whole is willing to fundamentally change its tactics in order to do so, is less obvious. Along similar lines to the continuous game analogy, resilience thinking reveals that systems dynamics are not rigid, rather can pass through multiple stable states (Gunderson & Holling, 2002; Folke, 2006). Again, this opens a vista to multiple plausible trajectories for sustainability planning — each assessed relative to time, place, present circumstances, and participating actors.

Emergent within the field of ecology, in 'novel ecosystems' discourse, state changes are assessed, in part, relative to human intervention or impact in non-human nature: *historical, hybrid*, *novel*, and *designer* ecosystems representing a transition from what is perceived to be a system's original, undisturbed set of conditions, to a distinct and irreversibly new composition and function (Hobbs, Higgs, & Harris, 2009; Hobbs, Higgs, & Hall, 2013). Novel ecosystems research makes space for variance in conventional conservation practice, challenging the inclination that is deeply entrenched in many ecology programs to maintain 'natural heritage', while also evoking the earlier question of *what kind of game are we playing?* as it relates to nature-culture interactions. In the era of the anthropocene (Crutzen, 2006), wherein 83% of terrestrial[1] and 41% of marine systems display signs of impact from human activity (Hobbs et al., 2009), it becomes less viable to classify the 'wild'

[1] Human Footprint Analysis. http://sedac.ciesin.columbia.edu/wildareas/.

as something removed from human influence. The presence of the human species within the biosphere is more than moderately conspicuous; not to mention, it has managed to successfully occupy multiple ecological niches, simultaneously. Perhaps it is time to evolve the old adage of 'stepping lightly' to 'stepping responsibly' — relinquishing any lingering guilt for an allegedly disruptive existence by taking ownership for one's place in the system. Novel ecosystems discourse reveals the trace of human agency in existing, resilient landscapes, suggesting that a co-evolution between social systems and non-human nature may be sustainably viable. It implies that, given the right touch, human-managed ecosystems[2] are capable of contributing to local contexts with ecosystem functions and services (Pearce, 2013), dispelling perceptions that all constructed landscapes are ecologically compromised. Facilitated by novel ecosystems perspectives, views of natural and man-made constructs might become indistinguishably interwoven: "…environmental history constantly portrays human beings and the natural world…as so entangled, so inseparable, that we do not produce the kind of purity that nature/culture divisions demand"(White, 2003, p.4).

While this perspective engenders a shift in conservation practice (Hobbs, Higgs, & Hall, 2013), it may also prove equally transformative for those in the business of developing and managing human settlements, with a penchant for sustainability planning. Novel ecosystems research, inadvertently as it may be, extends an olive branch between ecology and development — two domains of work seemingly at odds. This opportunity comes at a moment in time where reconciliation between these worlds would appear to be crucial. In light of contemporary environmental pressures, revaluation of the parameters of the human presence within the biosphere is imperative — and what better conceptual frame to represent this than settlement systems? Where novel ecosystems discourse begins to unhinge interpretations of the 'natural' as it pertains to work in preservation/conservation ecology, it indirectly opens the door to redefine this term as associated with all other human endeavour: settlements take their place as one part of biosphere ecology, the natural-artificial dichotomy requiring a different filter than 'man-made'. For example, an assessment of degree of integration within and functional contribution to the system as a whole might suffice — something we later describe as 'entrenchment'. So, while development itself need not be relegated entirely to the realm of the 'unnatural', certain development trajectories perhaps can be classified as such. 'Unnaturalness' as a characteristic can seemingly be perceived, based on the grievances that modern, industrial societies have distanced populations from their connection with the non-human natural world (T. Roszak in Mishlove, 2010). On these terms, settlement systems might be critiqued less as 'unnatural' as they are out of place, dis-embedded, or dis-entrenched from the remainder of the non-human natural ecosystem in which they are situated. At least, large metropolitan regions in their current state do not seemingly evoke cradle to cradle (McDonough & Braungart, 2002; 2013) or Gaian (Lovelock, 1979) visions of interconnected symbiosis; nor likely would they, arguably, even with a comprehensive rollout of existing sustainability technologies. Even metaphorical comparison of cities to organisms or ecosystems, employed as a design device, does not guarantee design outcomes that are integrated with local contexts, unless explicitly developed with this intention[3] — arguably, approaches for doing so within large metropolitan regions have yet to be discovered. So, while the human species is evidently part of the greater community of biotic life, and by this right, its

[2] Pearce (2013) refers to traditional and contemporary agricultural practices, that integrate production with conservation. It should also be clarified, however, that the works contained in Hobbs, Higgs, and Hall (2013) deliberate how to qualify intentional acts of human agency in the definition of novel ecosystems.

[3] Bettencourt (2013) critiques the use of the term 'ecosystem' as a design metaphor, for often leading to design interpretations that emphasize form over function.

constructed products as natural as any termite mound or bird nest, the means by which it might accomplish the kind of operational integration conjured by McDonough and Braungart (2002; 2013) or Lovelock (1979), working from the existing social-technological regime, is not immediately apparent. Importantly, when we refer to 'entrenchment', we mean to apply this to human cultures as a whole. As such, prospective solutions should have "durability, scale and impact" (Westley & Antadze, 2009) within the context of current regimes, rather than being applied explicitly to exclusive eco-communities. Novel ecosystems discourse, indirectly and unintentionally, creates a space wherein designers and ecologists, together, might consider how ecosystems and settlements could each be organized to the benefit of the other, renewing the models by which ecosystems are inhabited.

The novel ecosystems story reads both as opportunity and caution. As the human species looks to deepen its relationship with the non-human natural world through work in ecology, environmental sciences, and sustainability practices, measured signals of irreversible human impact on terrestrial, aquatic, and atmospheric systems only become more evident (Crutzen, 2006; Hobbs, Higgs, & Hall, 2013). While, these findings tend to invite a cosmological positioning of humanity as a disruptive agent within a fragile system, amplifying perceptions of its separation from the remainder of the living world, novel ecosystems simultaneously points in the other direction, positioning the species as a co-creative agent. Acceptance of the latter argument suggests that a co-creative approach may prospectively resolve the problems laden in the former. It opens ones eyes and ears to the inevitable flux that is life on earth, and asks constructive human agents, not to dampen their voices, but to harmonize them with the flow in which they stand. Such an approach in the development and management of human settlements might entail simultaneous acts of preservation and reinvention, rooting the species' innate creative spirit in a humble reverence for the genius of life (Benyus, 1997), the results garnering a certain kind of social-ecological novelty: "urbanization is not merely a linear distancing of human life from nature, but rather a process by which new and more complex relationships of society and nature are created"(Roger Keil in Kinkela, 2009, p.906) — "these worlds will themselves be hybrids" (White, 2003, p.9).

Before eagerly forging ahead with the construction of these hybridized schemes, however, there is another part of this story that deserves notice. If humans have, indeed, been involved in a 60,000 year process of co-creation with the biosphere, how is it that this social-ecological entanglement has, for all intents and purposes, become socially dominant? Why is it that the creative expression inherent in the evolution of human civilizations, has left in its wake, time and again, a trail of ecological destruction? The deep ecology school of thought (Devall & Sessions, 1985; Naess, 1989) suggests that this is not only a technical predicament, but also a philosophical one: "… 'man's essence lies in the very contradiction between his being in nature… transcending nature by…the fact of his awareness – of himself, of others, of the past and the present.' Man is separated from nature, yet part of it. He is homeless, yet chained to the home he shares with all creatures" (E. Fromm in Capra, 1996, p.57). Notions of separation, of difference, of incompatibility, of a threatening wild to be tamed, or a harsh climate to be pacified, establish a hostile relational position. Even perceptions of a fragile system to be protected can be paternalistic, and imply a power disparity. From a vantage point where the human species is considered a destructive agent, conservation work can resonate like the voice of a protective father, redeeming the vulnerable from the realities of the harsh world of urbanization. If conservation and development, sustainability and consumption, are pitted as opponents, there is less incentive to forge a congenial bond. Deep ecology and biosphere

consciousness perspectives coax sustainability strategies beyond mitigation of ecological footprint, reduction of resource use, and stewardship of natural assets, imploring, in addition to these techniques, the adoption of a relational outlook that is founded in reciprocity and partnership (Rifkin, 2009). While deep ecology was intended as a critique of anthropocentric approaches to ecology (Capra, 1996), its premises can extend more broadly to inform life orientation and ways of being. This is subtly, however crucially, distinct from engaging with systems or ecosystems thinking as a functional science, as it assumes that a profound connection to the natural world is intrinsic: "When the concept of the human spirit is understood as the mode of consciousness in which the individual feels a sense of belonging, of connectedness, to the cosmos as a whole, it becomes clear that ecological awareness is spiritual in its deepest essence" (Capra, 1996, p.7). Without this sensibility, the management of ecosystems will always take place from an externalized position. When non-human environments are treated not simply as a set of operational conditions, but an adapted demonstration of biosphere expertise to be revered and studied (Benyus, 1997), the quality of interaction with these systems will shift. Applications of this kind of approach are beginning to take shape in design contexts through biomimicry practice (Benyus, 1997). Biomimicry also promises design innovation through intimacy with the natural world. In this light, if one assumes that human settlements are an expression of life orientation, as inspired by specific worldviews, would a shift in philosophical foundations modify existing conceptions of 'systems optimization', thus leading to new models for sustainability? While not specifically intended as a philosophical stance, the kind of emergent co-evolutionary processes articulated by novel ecosystems findings points to active engagement between nature and culture as a pathway to social-ecological innovation.

Given the apparent incongruity between the operation of human settlements and natural ecosystems, it can be too easy to retreat from the social dimension of this conversation, with an inclination to buttress the seemingly weaker side — the ecosystems that dwindle in the wake of human impact. But weighting ecological policy toward designated protected areas may inadvertently relieve settled areas from environmental responsibility, and underrepresent the need for reform in these regions (Folke, Holling, & Perrings, 1996). Per Lovelock's Gaian hypothesis, this does not explicitly imply that large-scale human systems are out of place in the biosphere's dynamic network, only that they have yet to find their 'fit'. Here, the view becomes murky, as most human settlements are, at present, highly engineered systems supporting large populations. While it is easy to position human life as an integral part of the biosphere, simply accepting human activity and its resulting technologies as an extension of nature risks dismissing environmental accountability (White, 2003). The current repertoire of human systems are so disintegrated that achieving a Gaian system of symbiotic co-dependence would seemingly entail nothing short of a long-term unwinding and considerable remodelling of rigid social-technological regimes. This would call not only for a strategy by which to discover this kind of symbiotic settlement model — based on the hybridization of social-ecological domains, for example — but also a scaled, phased, and socially embedded process of reinvention. No doubt, the scope of such a challenge is significant, and thus, the arguments for including it in a long-range sustainability strategy are worth examination. A case for entrenchment, in which the human species intentionally constructs its own activities as part of the natural course of living systems, is underdeveloped. The extent to which it attempts to do so might reveal multiple possible sustainability pathways. Experimentation with social-ecological novelty, on a small scale, and through active engagement with non-human nature, presents an entry point into, what is certain to be an uncertain journey. Thus, by embracing a novel ecosystems approach, designers and

ecologists may ultimately find common ground in conceiving of large-scale human systems as embedded in inhabited ecosystems; or rather, designing novel social-ecological systems. Moreover, ecosystem thinking is especially well positioned to enrich sustainable design discourse, *because* it implies structural, compositional, and functional characteristics in a system, and therefore illuminates possibilities for practical design applications. Of course, worldviews cannot be excluded from an analysis of complex dynamics. In this case, it is useful to ask not only how shifting worldviews have been reflected in practice, but also what the emerging age of ecology demands on practical terms.

Establishing a Place in Space

Human settlements are more than mere cultural artifacts (Mehaffy, 2014) — they are a magnet for and containers of human cultural systems, the emblematic expression of human endeavour, and the support system for human life. They are socially constructed systems that interface between the human species and the biosphere, directly coordinating and mediating the debated nature-culture relationship, while managing the provision of basic necessities. In 'biomimicry' (Benyus, 1997) terms, they represent the human species' unique, adaptive approach to survival within the conditions presented by this home planet; and, have been modified over time in response to changing social-ecological conditions. In their role as a mediator and bridge, settlements serve as a useful conceptual boundary through which to understand the relational dynamics between humanity and biosphere, and from this conceive of pathways to sustainable ways of life. By this right, they are also symbolic of the species' interpretation of its place in this space, and perhaps betray the alleged sense of alienation from its inhabited places.

Human civilizations are certainly noticeable among other biotic communities as a globally dominant presence, the impact of their development echoed across terrestrial, marine, and atmospheric systems (Steffen et al., 2007; Hobbs, Higgs, & Hall, 2013). Needless to say, they also clearly demonstrate the expressive, creative, and inventive tendencies of the species. A trait that is both remarkable and daunting, the human capacity to reorganize and reinvent the conditions in which it exists means that, within human cultural development, novelty is commonplace. The extent to which it presents as an evolutionary advantage is debatable. The aptitude for novelty creation only implies an adaptive capacity that stands out from the remainder of non-human nature: "Cultural change operates by mechanisms that can validate a *general and driven trend* to technological progress — so very different from the minor and passive trend that Darwinian processes permit in the realm of natural evolution" (Gould, 1996, p.223). By virtue of cumulative, collaborative efforts, facilitated through the symbolic codification of knowledge, and stacked across generations and continents, the complexity and expansion of human cultures only continues to intensify (Christian, 2004). Of course, this does not guarantee advancement toward any normative understanding of 'progress' relative to sustainability criteria, as not all invention serves the welfare of life and communities (Diamond, 1995). Too soon can the sense of empowerment that accompanies the ability to maneuver within known natural laws result in an overly technologized world, lacking in both biodiversity and self-organizing resilience. Moreover, this evolutionary asset, when overexpressed, has the potential to translate into the species' greatest flaw (Kaplan & Kaiser, 2009; Lappé, 2011) — the capacity to manipulate both nature and culture potentially propagating habits of "what Riane Eisler has called the 'dominator system' of social organization" (Capra, 1996, p.8). On

the other hand, in their examination of constructal law, Bejan and Pedar Zane (2012) imply that design exploration eventually tends toward systems optimization. Just as non-human nature follows a continuous process of restructuring to improve systems flows, so they assert, so too do human cultures. Their argument positions reinvention as an adaptive process, the resulting collection of cultural products improving the species' overall efficiency in accomplishing any given end: "For humanity, culture is the endless list of flow architectures we have created that cover and sweep the globe. These include all the known and still unknown forms of human movement — walking, working, and staying alive by using and developing enhancements that make life easier: knowledge, shelter, hygiene, language, writing, social organization, music, visual arts, and the running stream of novelties, inventions, and secrets unlocked" (p.233-324)…Culture is the knowledge to produce, harness, distribute, and use power" (p.335-336). Their proposition that cultural evolution takes place in a predictable direction toward thermodynamic optimization begs the question whether all change is inherently moving along a sustainability pathway. This kind of argument works best on a macro scale, if one considers, for example, the global interconnection afforded by contemporary transportation and communication infrastructures to propagate resilience and efficiency, thus validating their related ecological footprints, to some extent. Such an argument would also depend on a complexity view of systems in a non-linear state of dynamic flux, moving through multiple stable states (Gunderson & Holling, 2002; Waltner-Toews et al., 2008). If processes of change are similarly non-linear, while cultural evolution may allegedly be moving *toward* optimization, the positions through which cultural systems pass on the way would not necessarily represent a linear progression. In this way, optimization would be considered an emergent phenomenon — the result of an amalgamation of multiple marginal moves. By this right, it is the cumulative effects of manifold discoveries and shifts, assimilated into local contexts over time, which lead toward new future states — ones which could not be envisioned in their entirety from the position of the present. Relative to the human tendency to reinvent, creative explorations exemplify these kinds of marginal moves: a collecting of knowledge, an attempt to improve one's fare within one's context, and perhaps also a subtle shift of one's interpretation of one's place in space.

That said, creative engagement with place, in a continual creation of novelty toward transformative ends, would appear to be integral to the species' life way — "Our urge to make things, to create things, is certainly as deep as the urge of the Sun to shine and the Earth to spin…"(Swimme & Tucker, 2011, p.116). If a penchant for invention is an inevitable part of human nature and behaviour, then sustainable life ways should, ostensibly, nurture this tendency, while also being cautious to find means by which to ground it: "Power is creating…And it is perhaps the most underappreciated human need… '[Man] is driven to make his imprint on the world, to transform and to change, and not only *to be* transformed and change…All these activities are the result of man's capacity to direct his will toward a goal and to sustain his effort until the goal is reached…If man is not able to *act* [he attempts] to restore his capacity…one was is...to destroy'" (E. Fromm in Lappé, 2011, p.192). To manage this creative habit relative to planetary parameters, the terms of this engagement deserve further clarification and evaluation: "Our human role is to deepen our consciousness in resonance with the dynamics of the fourteen-billion-year creative event in which we find ourselves" (Swimme & Tucker, 2011, p.116). To begin, one might emphasize that invention, always occurs within a context. In Fuller's words, viable new inventions are not fanciful constructions of the imagination (Edmonson, 1986), rather, they appeal to a sophisticated understanding of the physical laws of the world in which they exist. Along similar lines, biomimicry (Benyus, 1997) as a

design strategy encourages close engagement with the natural world, at least as a respectful observer. Along these lines, design as an adaptive capacity is less an act of creative expression, and more a response to direct experience. Situated within specific environments, creative agents apply the collective savvy of their inventive minds to shape their lived experiences. Through prolonged interaction with any given environment, one might find more effective means of surviving in said location; or, discover the "adjacent possible" (Johnson, 2010) that hovers closely to the existing social-ecological landscape. These responses will be 'constructed', although not exclusively technological. What this suggests is that, in addition to the coordination of political will, sustainability strategies should also include a search for distinctly new ways of inhabiting places; ways that are inspired by the human proclivity for reinvention, while grounded by the kind of environmental accountability that accompanies Rifkin's (2009) biosphere consciousness; ways that integrate the knowledge and psycho-social shifts that have been gained through the multiple marginal moves of the past few thousand years of cultural evolution, while also reverential to the natural heritage that continues to support human populations. For example, in his appeal for a critical regionalism, Frampton (1983) encourages developing a "dialectical relation with nature", addressing the "idiosyncrasies of place...without falling into [nostalgic] sentimentality" (p.26).

Social-Ecological Novelty as A Function of Complexity

Novel ecosystems discourse reveals that traces of societies long past remain in contemporary landscapes — even those which are no longer occupied for human purposes, and have been left to exist in a state of self-organizing 'wildness'[4] (Pearce, 2013). A similar idea can apply to settled regions: traces of societies long past remain in constructed environments,[5] meaning that for ecologists and designers alike, there is really no opportunity to start with a clean slate, in the purest sense. Every context presents a set of conditions that have been in dynamic flux since before the arrival of homo sapiens; flux in which social and ecological factors each influenced changes within the other; flux through which the nature of the relationship between the human species and the biosphere evolved; flux in which the emergence of social-ecological novelty has also been accompanied by increased complexity.

Arguably, this is the case with the development of settlement systems, as Kiel points out, settled regions representing increasingly complexified relationships between nature and culture (Kinkela, 2009). From Arthur's (2009) position, wherein complexity is cumulative, it is almost inevitable that the components of cultural systems would continue to combine and hybridize in more complex variations, over time, complexity merely an outcome of evolution. While complexity in itself is neither something to be lauded nor avoided, it is useful to identify the scale of complexity that is currently supporting global populations, and the social-technological regimes that uphold this. For example, by 2010 roughly 50% of the global population was living in urban regions, and this is anticipated to increase to 75-80% by the end of the century, while population numbers also jump by roughly 2-4 billion (Angel, 2012). Generally, when one thinks of a contemporary urban region, what

[4] Citing a study by geographer, Erle Ellis, Pearce (2013) indicates that "at least one fifth of the land across most of the world had been transformed by humans as early as 5,000 years ago". Specifically, he notes that portions of today's Amazon rainforest, and other tropical rainforests, were once farmed.

[5] For example, see more on the buried layers of the city of Rome: http://www.theatlantic.com/magazine/archive/1997/04/underground-rome/376836/

might come to mind are heavily industrialized and digitized systems. We will not posit here the extent to which the current levels of complexity which uphold these systems might need to be scaled back as part of sustainability and resilience planning, rather posit that adaptive hybridization[6] as a process of systems' reordering may be equally viable. The emergence of social-ecological novelty as it relates, for example, to the domestication of plants and animals, has been just that — emergent (Budiansky, 1992). The question is whether civilizations can and should consciously adopt social-ecological co-evolution, characteristic of an *adaptive* transition process, as a resilience technique. As Young et al. (2006) state: "stability in ecosystems has been attributed to the fact that in nature, ecological connectedness results from a long history of co-evolution, selection and mutual adjustments, rather than from an arbitrary assemblage of many species put together at random" (p.309). In other words, the incremental discovery of settlement reform would be more in line with a resilience approach than proposing and imposing a redesigned 'eco-future'. Collapse from one state and transition to the next would take place so gradually that the impact of the disruptions would be distributed over time.

Needless to say, an incremental process of adaptation would always take place relative to one's current position. In other words, one necessarily moves from within the current social-technological regime in which one operates: for example, the existing settlement systems that act as bridge to the biosphere. Working toward social-ecological integration with a complexity view, would neither ask populations to abandon these systems, nor even to retrofit them with the existing suite of sustainable technologies. As settlement systems already represent constructs of social-ecological complexity, so too can their reform. It should be noted, however, that the kind of complexity implied in this discussion is of a specific variety. For example, a rise in complexity, in certain cases, might be characterized by an increase in structural, compositional, and operational intricacy, this also perhaps implicating an increase in a system's fragility and energy footprint (Christian, 2004). Conversely, other types of complexity may demonstrate conceptual sophistication brought about through the combination (or, what G. Whitesides, refers to as stacking) and refinement of multiple previous discoveries (Arthur, 2009), while the operation of the system as a whole has been simplified (Whitesides, 2010). Ideally, this kind of simplification through conceptual complexity could produce schemes that accomplish systems efficiencies, for example, a reduction in material or energy use, or even increased productivity. This is only to say that there is a place for the pursuit of novelty, invention, and innovation in sustainability pathways (Westley et al., 2011). Along the same lines as Bejan and Peder Zane's (2012) argument that both natural and cultural systems evolve toward optimization, conceptual complexity in cultural systems could be viewed as a maturing of cultural knowledge toward greater effectiveness. Of course, as discussed earlier, one might assume that there would be some trial and error along the way, deflating any notion of linear 'progress'.

Yet, again, to state that all conceptual complexity might produce greater effectiveness could be as imprecisely misleading as the argument that all human technologies are part of the natural order of things, or that all redesigns engender systems optimization. Rather, these ideas are useful to open the borders of exploration in sustainability planning in settlements, on the premises that

[6] Here, our use of the term 'hybrid' is more generic than its use in novel ecosystems discourse. In its classification of ecosystem states, novel ecosystems discourse distinguishes between 'hybrid' and 'novel' forms. Hybrid systems are characterized by the co-existence of social and ecological uses, where novel ecosystems are defined as having undergone phase shifts, away from their historical precedents, as a result of human impact (Hobbs, Higgs, & Harris, 2009).

assuming a co-creative role could be a welcome change in ecosystem management; that further social-ecological integration in settlements is schematically plausible, and that these novel schemes have yet to be discovered; and, that new sustainable settlements models could conceivably reflect an increase in social-ecological complexity. With this trilogy of claims duly endorsing the value of human endeavour within the greater scheme of sustainability, a sobering counterbalance would be worthwhile. If one accepts that, within settled regions, novelty is to be expected, this still gives little guidance as to the type of novelty that should be pursued. For this, another filter is necessary: one which could help steer iterative reinvention in a useful direction along an adaptive pathway, and assess whether the emerging novelty engenders a better 'fit' of settlement systems within inhabited ecosystems.

From Enchantment to Entrenchment

Entrenchment of human cultures in biosphere systems is, for all intents and purposes, automatic, regardless of perceptions and behaviours. The human species *is* a part of the sum total collection of biotic life; it *is* part of an interconnected web; its various activities *are* metabolically processed through their local ecosystems. Nevertheless, through both perceptual and behavioural factors, a nature-culture separation can still be expressed tangibly. Roszak (in Mishlove, 2010) identifies a pervasive sense of alienation as a contemporary cultural psychopathy — a collective 'madness' he attributes to urban industrial societies' lack of balance with non-human natural environments. Where Roszak's 'ecopsycology' (1992) can frame a broader conversation regarding the interplay between experience, perception, and behaviour, our interest here is situated primarily in the domain of the latter, while also considering how work in the former two can pave a road to behavioural shifts. With reference to the design and management of human settlement systems, it is not yet clear the extent to which the perceptions of biosphere interconnection representative of this 'age of ecology' could become manifest. While the conscious or subconscious realignment of perceptions related to the nature-culture dynamic may be important to sustainability transitions (Berman, 1981; Roszak, 1992; Rifkin, 2009), so too is the continued search for applied approaches to ecological integration of settlement systems.

Enabling shifts in perspective, as impetus for sustainability movements, is substantively different than embracing a concept like biosphere consciousness (Rifkin, 2009) to shape sustainable design mandates. Supporting value sets related to sustainability or resilience discourse does not inherently point to practical pathways for their implementation. Valuing an ecosystem in principle does not mean one knows how to cultivate a relationship founded in reciprocity. Believing that one is part of an interconnected whole does not warrant that one has the logistical capacity to act on this in ways that are anything more than nominal. Between the philosophical adoption of a biosphere consciousness (Rifkin, 2009) and the development of sustainable and resilient settlement models, exists a wide field of interpretation. As it stands, observations of nature-culture relational dynamics are already expressed as a range, for example: some highlight the dependency of human wellbeing on ecosystem health (Carson, 1962; Howard, 2005), while others articulate the link between the harvesting of ecosystem resources and prosperity in human economies (Daly & Townsend, 1993); some identify the human species' psycho-spiritual bond with the natural world (Roszak, 1992; Kellert & Wilson, 1993), and others point out the inevitable interconnection of all living things (Capra, 1996; Rifkin, 2009). One can imagine how working with each of these premises, separately, could provoke a

different approach to management and design; for example, the first two notions might emphasize functional criteria, while the second two might focus on aesthetics, intrinsic values, and an evolving interpretation of contextual variables. In other words, translating between philosophy and practice has the potential to follow multiple routes; and, with novelty as a common occurrence in contemporary cultures, one could use both qualitative and quantitative measures by which to interpret alignment between the two, in assessing available options.

At this stage, it is understandable if one's philosophical frames and practical approach to sustainability planning are, at times, misaligned. Even those who do embrace a cosmological position of interconnection on a deeply personal level may not know how to reflect this within the context of contemporary cultural complexity. There is still much interpretation and evaluation needed to understand how such philosophies might be expressed through means that are personally significant, ecologically transformative, and also culturally relevant. It might be argued that the specific techniques to do so have yet to be discovered. Where Berman's (1981) 'reenchantment' appeals for an intuitive and philosophical transition from cosmological alienation to earth-based interconnection, here we will introduce the term **'entrenchment'** to explore the practical complement to such a shift. We will define entrenchment as the degree to which a population is able to interpret and respond to the contexts in which it is situated, such that it engages in a process of reciprocal exchange with its environments. By this right, ideas of 'interconnection' and 'reciprocity' would initially be place-bound; while, interpretations of these terms relative to a collection of places would later become planet-bound. Of course, with the human species included as one ecosystem variable, health and prosperity for human cultural systems would naturally be a consideration in the evaluation of degrees of entrenchment. It is here that the concept of the dynamic network takes primacy, whereby assessment of the 'entrenchment' of any given system component would be relative to the nature of its interactions with the system as a whole. Referring to Bejan and Peder Zane's (2012) point that systems optimization is a conceivable outcome of cultural evolution, it is plausible that the discovery of a more deeply entrenched position of cultural systems in non-human ecosystems could unfold over time. Further to this, following the logic of biomimicry (Benyus, 1997), one might assume that there is opportunity for the exploration of technological approaches that are reflective of and embedded in natural systems. In this regard, prolonged and close interaction with specific places (as implied in the biomimicry approach), inspired by the ecophilosophies indicative of the time (as implied by the age of ecology), and with a view to the co-evolution of social-ecological novelty (as implied by novel ecosystems work), might ultimately produce new ecosystems technologies: a process of social-ecological 'sensemaking'[7] as it were. Developing a concept of 'entrenchment' could serve as a guide for emerging novelty.

Entrenchment of Contemporary Settlement Systems

It might seem obvious to accept human endeavour as part of the natural order of things, on the grounds that it is the product of nature's own, however, it would be remiss to then suggest that this supposed 'naturalness' automatically warrants these activities as suitable for sustainability pathways; or, that all human systems in their current state could remain operable within planetary boundaries

[7] " Sensemaking is 'defined as "how people make sense out of their experience in the world" ' (Klein, Moon, & Hoffman, 2006, p.70), and is at the heart of how we create meaning, interpret value, and subsequently make decisions amidst complexity, uncertainty, and unknowing (Ruttonsha & Quilley, 2015).

(Rockström et al., 2009) over the long term. In consideration of settlement systems as an interpretive boundary for the human species' relationship with the biosphere, paradox arises. It has been shown that large-scale, extensively engineered urban systems can offer social-ecological efficiencies (Brand, 2009; Bettencourt, 2013; Mehaffy, 2014); and yet, they are also "the principal sources of our social and environmental problems" (Bettencourt, 2008, p.285; Ravetz, 2011). If nothing else, the aesthetics of these systems, ostensibly, reinforce a lived experience of nature-culture separation for their inhabitants. While metropolitan jungles, overrun with concrete high-rises and crippled by traffic congestion, may appear a far stretch from Shangri-La (Hilton, 1933), statistics on their sustainability performance might redeem their merit: " '…the energy metabolism of metropolitan areas slows down as they increase in size: larger regions burn less energy per capita than smaller regions…'"(Martin Prosperity Institute in Kalan, 2014). This critique of the benefits and drawbacks of urban systems parallels the innovation paradox described by Westley, Olsson, Folke, Homer-Dixon, Vredenburg, Loorbach, Thompson, Nilsson, Lambin, Sendzimir, Banerjee, Galaz, & van der Leeuw, 2011: "Large-scale transformations in information technology, nano- and biotechnology, and new energy systems have the potential to significantly improve our lives; but if, in framing them, our globalized society fails to consider the capacity of the biosphere, there is a risk that unsustainable development pathways may be reinforced"(p.762).

The efficiencies that urban systems achieve renders it unclear whether sustainability and resilience pathways call for an explicit, reciprocal tie between nature and culture, or even how such a dynamic might be articulated. For example, one might imagine highly engineered technospheres that are low impact, but segregated from the natural environment as a respectably viable option. In their "cradle to cradle" premise, McDonough and Braungart (2002) separate technical and biological nutrient streams, with 'artificial' products recycled as part of a closed loop that refrains from interacting with 'biological' nature. At the same time, green infrastructure such as living walls, green roofs, and vertical gardens/farms exhibit built form taking on nature-like qualities. Conceptually, both of these approaches — the optimized technosphere and the urban garden — could be considered a valid expression of Lovelock's (1979) Gaia, although the latter certainly appeals more strongly to the requests of Kellert & Wilson's (1993) biophilia hypothesis. This is not to suggest that either has accomplished such an expression to a satisfying degree. As Keil (in Kinkela, 2009) indicates, the process of urbanization will continue to beget " 'new and more complex relationships of society and nature' " (p.906). The piece of this relationship that would appear more elusive to grapple with are the structures, processes, and drivers of social organization that yield the products, spaces, and infrastructures characteristic of these urban places. For example, there are several sustainable design techniques and strategies that can be implemented today, which focus primarily on the retrofit or redesign of that which is tangible, such as: passive building orientation (Snell, 2004); building re-skinning for envelope efficiency; industrial ecology (Rosen, 2003); material recycling; rainwater collection; fog capture (Biomimicry Institute, n.d.); greywater recycling; bio-filtration (John Todd Ecological Design, n.d.); low-flow and waterless fixtures; bio, wind, geothermal, and solar energy; living walls; green roofs; xeriscaping; and, smart appliances. These approaches illustrate an optimized use of resources, the development of green infrastructure, and the formulation of metabolic-like processes; yet, are shy in unwinding the cultural norms that reinforce the ways in which populations use materials, energy, products, spaces, and infrastructures, in the first place.

As such, the search for sustainable design techniques may, in fact, distract from the discovery of macro-scale solutions to the challenge of nature-culture disintegration. While retrofitting existing

built form may improve a settlement's current sustainability performance, reinvesting in these infrastructures implicitly validates their existence within the city plan — this reinforcing the current plan, and side-lining long-term views for adaptive transformation. In Dusch, Crilly & Moultrie's (n.d.) evaluation of sustainable development strategies, their systems' approach (compared to eco-centric and techno-centric approaches) demands "creating new scenarios for sustainable life styles", over and above the redesign of products, services and/or production systems. Further to their point, though it is useful to analyze the lifecycle impact of technologies and infrastructures, one should not overlook the cultural habits and preferences that justify and propagate their development. Also not to be overlooked are the large-scale, political-economic engines that manage the infrastructural domain. As such, pathways for sustainability should comprise not only a technological shift, but also a profound transformation in "basic routines, resource and authority flows, or beliefs" (Westley & Antadze, 2009, p.2). In other words, an extensive illustration of the concept of entrenchment would extend beyond the development of form, and infiltrate the realm of social interaction:

> "…ecology has been used only in the context of some thing called the 'environment,' which is generally thought to be of 'nature' and exclusive of the city. Even those who have included the city in the ecological equation have done so only from the perspective of natural systems (hydrology, air-flow, vegetational communities, and so on). We have yet to understand cultural, social, political, and economic environments as embedded in a symmetrical with the 'natural' world. The promise of landscape urbanism is the development of a space-time ecology that treats all forces and agents working in the urban field and considers them as continuous networks of inter-relationships" (Corner, 2006, p.30).

Wild of Heart, Measured of Mind

While wilderness as a constructed idea may conjure visions of harsh, inhospitable, and unyielding territories, from the context wherein this paper was written, the landscapes have been accommodating enough to be levelled for settlement. Both convey positions of exclusion — exclusion of culture from wild spaces, and exclusion of self-organizing nature from inhabited ones. Conversely, novel ecosystems discourse presents an opportunity for integration, whereby each of culture and nature might become more like the other within settled regions. From the ecological side of the equation, this kind of integration is needed more than ever, as it becomes clear that the impact of human cultural systems is leading to environmental degradation (Steffen et al., 2007). From the cultural side of this equation, integration is equally critical, as it has been pointed out that the biophilic (Kellert & Wilson, 1993) and ecological unconscious (T. Roszak in Mishlove, 2010) aspects of human nature thrive on an intimate connection with the non-human natural world. In this light, one might arrive at a position of 'cultured wildness', refined over time by the wild of heart and measured of mind. Such a position might encourage self-organizing, ecological abundance within inhabited quarters, while also exhibiting highly evolved ecosystems technologies. Such a position might be discovered through the tacit knowing garnered through a close engagement with place, indicative of traditional ecological knowledge (Ausubel, 2012), and combined with the savvy of an inventive mind. Such an approach might ultimately lead to settlement systems that engender a closer 'fit' within local ecosystems. The 'call of the wild' conjured by Roszak (1992) and Kellert and Wilson

(1993) can be accommodated, to some extent, in settled regions, and interaction with nature made a common, localized affair.

Conclusion

In a complementary paper (Ruttonsha & Quilley, 2015), we develop a multi-layered perspective of strategic design thinking for systems transformation: "...influencing perspective could influence practice that in turn could influence progress" (E. Young in Westley, Patton, & Zimmerman, 2006, p.16). In the case of interpreting human settlements as 'designer ecosystems' the perspective that is emergent is one wherein the human species is recognized as a co-creative agent within inhabited ecosystems; the practices that would complement this shift are still nascent in conservation ecology, and an opportunity to concurrently apply similar thinking in the development of settled regions is on the horizon. Progress perhaps arrives when these two worlds — ecology and development — find such a means of interconnecting that cultural activities are able to "promote [the] creative growth" of human endeavour within the operational parameters of local ecosystems (Mehaffy, 2014), or even produce net ecosystems gains. Novel ecosystems discourse can begin to orient ecologists and designers, together, toward such a position.

Works Cited

Aaltonen, M. (2007). *The third lens: Multi-ontology sensemaking and strategic decision-making.* Burlington, VT: Ashgate.

Alexander, C. (2002). *The nature of order: An essay on the art of building and the nature of the universe.* Berkeley, CA: Center for Environmental Structure.

Angel, S. (2012). *Planet of cities.* Cambridge, MA: Lincoln Institute of Land Policy.

Arthur, B. (2009). *The nature of technology: What it is and how it evolves.* New York, NY: Free Press.

Ausubel, K. (2012). *Dreaming the future: Reimagining civilization in the age of nature.* White River Junction, VT: Chelsea Green Publishing.

Batty, M. (2013). *The new science of cities.* Cambridge, MA: MIT Press.

Bejan, A. & Peder Zane, J. (2012). *Design in nature: How the constructal law governs evolution in biology, physics, technology and social organization*. New York, NY: Doubleday.

Benyus, J. (1997). *Biomimicry: Innovation inspired by nature, 1st Edition.* New York, NY: Morrow.

Berman, M. (1981). *The reenchantment of the world.* New York, NY: Cornell University Press.

Bettencourt, L. (2013). The origins of scaling in cities. *Science, 340,* 1438-1441.

Biomimcry 3.8. (n.d.). *Biomimicry design lens*. Retrieved from http://biomimicry.net/about/biomimicry/biomimicry-designlens/

Biomimicry Institute (n.d.). *Ask Nature, Water Vapour Harvesting, Namib Desert Beetle*. Retrieved from http://www.asknature.org/strategy/dc2127c6d0008a6c7748e4e4474e7aa1

Brand, S. (1999). *The clock of the long now: Time and responsibility, 1st Edition.* New York, NY: Basic Books.

Brand, S. (2009). *The whole earth discipline.* New York, NY: Viking.

Budiansky, S. (1992). *The Covenant of the wild: Why animals chose domestication.* New York, NY: W Morrow.

Capra, F. (1996). *The web of life: A new scientific understanding of living systems.* New York, NY: Anchor Books.

Capra, F. (2002). *The hidden connections: Integrating the biological, cognitive, and social dimensions of life into a science of sustainability.* New York, NY: Doubleday.

Carson, R. (1962). *Silent Spring.* Boston, MA: Houghton Mifflin.

Cayley, D. (1991). *The age of ecology.* Toronto, ON: James Lorimer & Company.

Chaisson, E.J. (2001). *Cosmic evolution: The rise of complexity in nature.* Cambridge, MA: Harvard University Press.

Christian, D. (2004). *Maps of time: An introduction to big history.* Berkeley, CA: University of California Press.

Corner, J. (2006) Terra fluxus. In C. Waldheim, *The landscape urbanism reader* (pp.21-33). New York, NY: Princeton Architectural Press.

Crutzen, P.J. (2006). The 'Anthropocene'. In E. Ehlers & K. Thomas (Eds.), *Earth system science in the anthropocene: Emerging issues and problems* (pp.13-26). Berlin, DE: Springer.

Daly, H. & Townsend, K.N. (1993). *Valuing the earth: Economics, ecology, ethics.* Cambridge, MA: MIT.

Devall, W. & Sessions, G. (1985). *Deep ecology: Living as if nature mattered*. Salt Lake City, UT: Gibbs M. Smith, Inc.

Diamond, J. (1995). The evolution of human inventiveness. In M.P. Murphy & L.A.J. O'Neil (Eds.), *What is life? The next fifty years: speculations on the future of biology* (pp. 41-55). Cambridge, MA: Cambridge University Press.

Dusch, B., Crilly, N. & Moultrie, J. (n.d.). *Developing a framework for mapping sustainable design activities.* Retrieved from http://www.drs2010.umontreal.ca/data/PDF/033.pdf

Edmonson, A. (1986). *A fuller explanation: The synergetic geometry of R. Buckminster Fuller* [NetLibrary version]. Retrieved from http://www.bfi.org/about-bucky/resources/books

Folke, C., Holling, C.S., & Perrings, C. (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications, 6*(4), 1018-1024.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change, 16*, 253-267.

Frampton, K. (1983). Toward a critical regionalism: Six points for an architecture of resistance. In H. Foster (Ed.), *The Anti-Aesthetic: Essays on Postmodern Culture* (pp. 16-30). Seattle, WA: Bay Press.

Funtowicz, S.O. & Ravetz, J.R. (1993). Science for the post-normal age. *Futures, 25*(7),739-755.

Geels, F.W. & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy, 36,* 399-417.

Gould, S.J. (1996). *Full house: The spread of excellence from Plato to Darwin*. New York, NY: Harmony Books.

Gunderson, L.H. & Holling, C.S. (2002). *Panarchy: Understanding transformations in human and natural systems.* Washington, D.C.: Island Press.

Hilton, J. (1933). *Lost Horizon.* New York, NY: Grosset & Dunlap.

Hobbs, R. J., Higgs, E., & Harris, J.A. (2009). Novel ecosystems: implications for conservation and restoration. *Trends in Ecology & Evolution, 24*(11), 599-605.

Hobbs, J.R., Higgs, E.S., & Hall, C.M. (Eds.). (2013). *Novel ecosystems: Intervening in the new ecological world order*. Hoboken, NJ: Wiley-Blackwell.

Homer-Dixon, T. (2009). The newest science: Replacing physics, ecology will be the master science of the 21st century. *Alternatives Journal, 35*(4), 8-11.

Howard, J. (2005). Ecosystem health: Prescribing a new vision for the future of medicine. *Alternatives Journal, 31*(3), 10-13.

John Todd Ecological Design. (n.d.). *About eco-machines.* Retrieved from http://www.toddecological.com/eco-machines/

Kalen, J. (2014, May 8). 10 million sardines in a sea of skyscrapers: How sprawling megacities – from Laos to Mumbai – may just save the world. *The FP Group.* Retrieved from http:// www.foreignpolicy.com/articles/2014/05/08/think_again_sprawling_megacities_lagos_mumbai _urbanizatio

Kaplan, R.E. & Kaiser, R.B. (2009). Managing yourself: Stop overdoing your strengths. *Harvard Business Review, 1,* 100-103.

Kellert, S.R., & Wilson, E.O. (1993). *The biophilia hypothesis.* Washington, DC: Island Press.

Kinkela, D. (2009). The ecological landscapes of Jane Jacobs and Rachel Carson. *American Quarterly, 61*(4), 905-928.

Klein, G., Moon, B., & Hoff man, R. (2006). Making sense of sensemaking 1: Alternative perspectives. *Intelligent Systems, 21*(4), 70-73.

Lappé, F.M. (2011). *EcoMind.* New York, NY: Nation Books.

Leopold, A. (1949). *A sand county almanac and sketches here and there*. New York, NY: Oxford University Press.

Lovelock, J. (1979). *Gaia: A new look at life on earth.* Oxford, UK: Oxford University Press.

McDonough, W. & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things.* New York, NY: North Point Press.

McDonough, W. & Braungart, M. (2013). *The upcycle: Beyond sustainability — designing for abundance, 1st Edition.* New York, NY: North Point Press.

Mehaffy, M. (2014, Sept 19). Five key themes emerging from the new 'science of cities'. *The Atlantic CityLab.* Retrieved from http://www.citylab.com/design/2014/09/5-key-themes-emerging-from-the-new-science-of-cities/380233/

Mishlove, J. (2010). *Theodore Roszak: Toward an ecopsycology* [Video File]. Oakland, CA: Thinking Allowed Productions. Retrieved from http://www.thinkingallowed.com/2troszak.html

Næss, A. (1989). *Ecology, community and lifestyle: Outline of an ecosophy* (D. Rothenberg, Trans.). Cambridge: Cambridge University Press.

Pearce, F. (2013, May 13). True nature: Revising ideas on what is pristine and wild. *Yale Environment 360: Opinion, Analysis, Reporting & Debate.* Retrieved from http://e360.yale.edu/feature/true_nature_ revising_ideas_on_what_is_ pristine_and_wild/2649/

Radkau, J. (2014). *The age of ecology, English edition.* Cambridge, UK. Polity Press.

Ravetz, J. (2011). Exploring creative cities for sustainability: Towards applications of relational visualization. In L.F. Girard, B. Tüzin, & P. Nijkamp (Eds.), *Sustainable city and creativity: promoting creative urban initiatives* (pp. 339-366). Burlington, VT: Ashgate Publishing Company.

Register, R. (2006). *Ecocities: Rebuilding cities in balance with nature, revised edition.* Gabriola Island, BC: New Society Publishers.

Rifkin, J. (2009). *The empathetic civilization: The race to global consciousness in a world in crisis.* New York, NY: Tarcher/Penguin.

Rittel, H. & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*, 155–169.

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society, 14*(2), 32. Retrieved from http://www.ecologyandsociety.org/vol14/iss2/art32

Rosen, C.M. (2003). Industrial ecology and the transformation of corporate environmental management: A business historian's perspective. In A. Molella & J. Bedi (Eds.), *Inventing for the environment* (pp. 319-372). Cambridge, MA: MIT Press.

Roszak, T. (1992). *Voice of the earth.* New York, NY: Simon & Schuster.

Ruttonsha, P. & Quilley, S. (2015). The many faces of design: From adaptive response to creative agency to immersive engagement [Conference Proceedings]. *Systemic Design: Emerging contexts for systems perspectives in design.* Oslo School of Architecture and Design.

Samson, P.R. & Pitt, D. (1999). *The biosphere and noosphere reader: Global environment, society, and change.* New York, NY; London, UK: Routledge.

Steffen, W., Crutzen, P.J., & McNeil, J.R. (2007). The Anthropocene: Are humans now overwhelming the great forces of nature? *Ambio, 36(8),* 614-621.

Swimme, B.T. & Tucker, M.E. (2011). *Journey of the universe.* New Haven, London: Yale University Press.

Tomalty, R. (2009). The ecology of cities: Urban planners are starting to see cities as complex systems that ought to be conceptualized in a way that mimics natural processes. *Alternatives Journal, 35*(4),18-21.

Walker, B. & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world.* Washington, DC: Island Press.

Waltner-Toews, D., Kay, J., & Lister, N.M.L. (2008). *The ecosystem approach: Complexity, uncertainty, and managing for sustainability.* New York, NY: Columbia University Press.

Westley, F., Patton, M.Q., & Zimmerman, B. (2006). *Getting to maybe: How the world is changed* [NetLibrary version]. Retrieved from www.torontopubliclibrary.ca

Westley, F. & Antadze, N. (2009). Making a difference: Strategies for scaling social innovation for greater impact. *The Innovation Journal, 15*(2), 1-18. Retrieved from http://sig.uwaterloo.ca/research-publications

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., Thompson, J., Nilsson, M., Lambin, E., Sendzimir, J., Banerjee, B., Galaz, V., & van der Leeuw, S. (2011). Tipping toward sustainability: Emerging pathways of transformation. *Ambio, 40*, 762–780.

White, R. (2003). Tempered dreams. In A. Molella & J. Bedi (Eds.), *Inventing for the environment* (pp. 3-10). Cambridge, MA: MIT Press.

Whitesides, G. (2010, February). *Toward a science of simplicity* [Video File]. Retrieved from http://www.ted.com/talks/george_whitesides_toward_a_science_of_simplicity?language=en#t-715568

Young, O.R., Berkhout, F., Gallopin, G.C., Janssen, M.A., Ostrom, E., & van der Leeuw, S. (2006). The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change, 16,* 304-316.