Recasting Paradigm Shift: "True" Sustainability and Complex Systems

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Abstract

Within environmental sociology there exists a debate between competing theories of societal development and its accompanying ecological repercussions and possible solutions. Environmental reform (ecological modernization) and unsustainable economic system (treadmill of production, ecological unequal exchange, and structural human ecology) theories propose two very different paths for the direction of society in addressing the multiple ecological crises of the 21st century. Both approaches provide theoretical and practical strides in addressing these questions within environmental sociology; however, both also fail to address important foci for the future. For us to continue to thrive as a species we must reconsider our relationship with nature and abandon our anthropocentric views of nature by taking a position that recognizes our role in a complex system. Ultimately, mechanisms for building resilience and adaptation and reducing vulnerability rely upon a paradigm shift, an understanding of "true" and "false" sustainability, and adaptation and resilience strategies that afford us an opportunity to recast social-ecological relationships towards "true" sustainability.

Key Words: *sustainability, "true" sustainability, "false" sustainability, paradigm shift, adaptation and resilience*

Introduction

There is growing evidence and increased recognition among physical scientists that global climate change presents a serious challenge for societies in the 21st century. Despite the recent controversies over the latest Intergovernmental Panel on Climate Change (IPCC) report, the scientific evidence for climate change is clearer than in previous reports (IPCC 2007a). Although global climate change is not the only environmental challenge it is thought to be the most pressing. In addition to providing a sound basis for the scientific understanding of anthropogenic climate change, the IPCC (2007b) has also placed the human dimensions of climate change — in the form of mitigation and adaptation — as important elements in seeking solutions to this problem. Most of the solutions put forward in the IPCC (2007b) report, however, focus upon technological, energy system and policy changes necessary for meeting the challenges in both the "short and medium term." It is noteworthy, however, that the IPCC (2007b) report acknowledges that "changes in lifestyle and behaviour [sic] patterns can contribute to climate change mitigation;" however, the report fails to address the long-term changes in worldview that are necessary to bring about a fundamental alteration in the ways in which humans interact with the environment. Likewise, the National Research Council's (2010) report "America's Climate Choices" advocates a "new paradigm" to manage climate change in the coming decades. Although the acknowledgment of the need for a new paradigm is welcomed, these organizations continue to be dominated by natural and physical scientists with little training in the social sciences. More than 30 years after William Catton and Riley Dunlap's (1978) call for a "new environmental paradigm" several facts seem clear: 1) sociologists have met this call with the emergence of environmental sociology as a viable sub-discipline; 2) a "new environmental paradigm" remains as an unfulfilled challenge; 3) technical environmental problems, such as global climate change, largely remain the purview of natural and physical sciences

indicating the need for cross-disciplinary research and educational opportunities.

We renew Catton and Dunlap's call for a new paradigm by recasting the discourse on "paradigm shift." Although we do not layout a blueprint for achieving such a change in worldviews, we offer four key elements that serve as guideposts for sociologists and non-sociologists in addressing this long-term project. First, we contextualize the contemporary debate within environmental sociology by highlighting the dominant theories in environmental sociology. Second, we renew the discussion on paradigm shift within the ongoing discourse on science and society. Third, we contextualize our understanding of paradigm shift within the context of "true" and "false" sustainability (Freese 1997). Finally, we propose an interdisciplinary approach, first advocated by Holling (1973), that points to the possibilities for a shift towards "true" sustainability through adaptation and resilience. Taken together, we think this provides a way forward for sociologists and non-sociologists to contribute to a meaningful, long-term transdisciplinary approach in bringing about a paradigm shift.

Environmental Sustainability and the Importance of Social Response

Within environmental sociology there exists an ongoing debate concerning the causes, consequences, and future paths for society with respect to various environmental problems, including global climate change, which looms as the most important of these problems. Although there are multiple lines of thought on these issues, there are two dominant theoretical strands that can be broadly defined as environmental reform and unsustainable economic systems. Although these are not the only theoretical approaches to understanding society-environment interactions, these approaches have been most influential within and, in some cases outside of, the discipline of sociology. Nonetheless, there are major differences between these two lines of thought. One line of reasoning, exemplified by ecological modernization theory, focuses upon social-ecological decisions and the continued expansion of economies and an accumulation of wealth, but with a shift in priorities resulting in new energy systems and a state-sanctioned (and led) emphasis upon ecological development (Mol 1995; Mol & Spaargaren 2000; Mol, Spaargaren, & Sonnenfeld 2009 Spaargaren & Mol 1992). The primary focus of this line of research is upon the future paths societies must take to become ecologically sustainable and can be labeled as environmental reform.

A second line of research is broadly defined as taking a more critical approach of the current economic system and its ecological effects. Although this line of reasoning has many strands, the argument centers upon the ways in which current economic systems in modern societies are ecologically unsustainable (Clark & York 2005; Dietz, Rosa, & York 2007; Foster 2005; Gould, Pellow, & Schnaiberg 2008; Jorgenson 2003; Jorgenson & Burns 2007; O'Connor 1998; Schnaiberg & Gould 2000; Schnaiberg 1980; York 2008; York, Rosa, & Dietz 2003; York, Rosa, & Dietz 2009).

Environmental reform and unsustainable economic system perspectives approach their subject matter from distinct viewpoints, but share some commonalities. As has been pointed out by Clark and York (2005) both theories are rooted in materialism although they draw very different conclusions. Likewise, both perspectives embrace a decidedly political economy analysis (Jorgensen & Clark 2009). However, they differ in large part due to positive interpretations of the future (environmental reform) and a preoccupation with documenting the limitations of the current system (unsustainable economic systems). We begin with the premise that although both theories provide important insights into understanding social-ecological interactions each falls short in important ways. The unsustainable economic systems perspective clearly demarcates how environmental degradation is tied, structurally, to existing capitalist systems of production that are inherently flawed; however, such theories fail to provide adequate means to overcome such impediments. On the other hand, environmental reform provides a path forward, but it is unclear that such a path is sustainable (see York & Rosa, 2003; York, 2008). Although ecological modernization may provide a means to "buy time" with respect to the worst effects of global climate change, it is not at all clear that it will result in permanently sustainable societies. We argue below that environmental reform likely reflects a "false" notion of sustainability (Freese, 1997). Nonetheless, the ideas embedded within environmental reform have gained traction in the public debate on global climate change responses and the move towards large-scale institutional change within capitalist markets is no longer a matter of if, but when and by whom (see Friedman 2008). Given this likely scenario, we do not consider the merits of such a project per se, but rather we consider the process of attempting to shift paradigms towards a "true" notion of sustainability (Freese).

Environmental Reform: Ecological Modernization Theory

The most well-known and developed theory of environmental reform is that of ecological modernization theory (EMT). EMT combines the ideas of modern, economic development with ecological sustainability. While many other theories consider capitalism and neo-liberalism a contradiction to ecological sustainability, EM theorists argue that change can occur from within the structures in place in society and through reforms of industrialization and advance-

ments in technology all of which will lead to the conditions necessary for ecological sustainability (Mol 1995; Mol & Spaargaren 2000; Mol, Spaargaren, & Sonnenfeld 2009; Spaargaren & Mol 1992). EMT is an answer to the degradation of the environment caused by rapid growth of industrializing nations (Hajer 1995). Although the theory began as a very loosely-knit combination of ideas with no standard statements to link them, as the 1990s drew to a close, uniformity in thought led to a fundamental belief that modernizing industry to conform to ecological standards would result in sustainable practices while maintaining economic growth (Weale 1992; Young 2000). This line of thinking presumes industry will take into consideration the health of its environment — an industrial conscience — as a response to ecological crisis (Mol 1995). In adopting this economic reform, capitalism is transformed into a responsible economic and ecological ethos that no longer operates in contrast to ecological realities of limited resources. For this to take place, it relies upon the notion that such an environmentally grounded ethos has both economic and ecological benefits (Mol, 1995).

It is the theory's unique idea that drastic change in the mode of production — capitalism — will not be needed in order to achieve ecological sustainability even though major refinements in the institutions that guide capitalism, particularly the nation-state, will be required (Spaargaren & Mol 1992). Mol & Spaargaren (2000, 23) state the following:

> *It is not that capitalism is considered to be essential for environmentally sound production and consumption (as neo-liberal scholars want us to believe), nor that capitalism is believed to play no role in environmental deterioration. But rather that (i) capitalism is changing constantly and one of the main triggers is related to environmental concerns, (ii) environmentally sound production and consumption is possible under different 'relations of production' and each mode of production requires its own environmental reform programme, and (iii) all major, fundamental alternatives to the present economic order have proved unfeasible according to various (economic, environmental and social) criteria.*

Consequently, capitalism is not the harbinger of ecological disaster, but rather the only viable means of economic production, albeit in need of retooling to meet the needs of an ecologically changing world. Within this theoretical assessment, the idea is of a pragmatic market that does not operate beyond its ecological boundaries emerges.

Although most of the nations of the world have yet to approach ecological modernization, the current global debate, reflected in the failed negotiations in Copenhagen, indicates that the world is moving ever closer to some practical applications of EMT. The results may be less than the EM theorists propose, but the reliance upon a combination of non-renewable and renewable forms of energy within the existing market system appears inevitable. The implementation of a market-based system that would leave capitalist modes of production in place are no longer in doubt, but rather the debate concerns the specific mechanisms through which such a system will be carried out in terms of monitoring and aid to developing countries. Although the energy systems may move from carbon-based energy systems to renewable systems, the overall trajectory of modern societies will not be altered. Hence, the environmental effects of this trajectory may result in fewer carbon emissions at some undetermined time in the future.

Unsustainable Economic Systems: Treadmill of Production, Unequal Ecological Exchange Theory, and Structural Human Ecology

In contrast to the ideas put forward in environmental reform theory, here we identify a set of theories that have in common the central feature that modern, capitalist systems of production are ecologically unsustainable. Each of these lines of argument has unique jumping off points and the argument here is not that they are indistinguishable — to the contrary, each adds a rich understanding to the current society-environment dilemma. However, they do share in common a similar critique of the world's dominant economic mode of production, capitalism, and its ecologically unsustainable logic. Each line of argument is equally suspicious that environmental reform via ecological modernization will resolve current environmental problems. Below we will highlight these perspectives with an emphasis upon their shared criticisms.

The treadmill of production (ToP) underscores the logic inherent in the modern industrial economy such that capitalism requires constant economic growth. The consequence of such a form of industrialization is that it degrades ecological systems by way of increased natural resource extraction and toxic additions to the environment (Schnaiberg 1980; Schnaiberg & Gould 2000; Gould, Pellow, & Schnaiberg 2008). Furthermore, the accumulation of capital is such that even as the overall economic pie grows, the rewards are unequally distributed (Schnaiberg 1980; Schnaiberg & Gould 2000; Gould, Pellow, & Schnaiberg 2008). As a result of massive reinvestment and excess capital steering political power, the treadmill of production has continued to gain speed and through neo-liberal economic global policies is now a globally active logic within capitalist production (Schniaberg 1980; Schnaiberg & Gould 2000; Gould, Pellow & Schnaiberg 2008).

The expansionistic tendencies of the ToP result in a global system in which the developed countries of the world exploit the labor and environment of dependent countries. Foster (1995) points out that a continuous 3 percent average annual rate of growth in industrial production would signify that world industry would double in size every twenty-five years. This underscores the ecological limits of the planet supplying the resources to produce and power the treadmill of production (Foster 2005; O'Connor 1998). Unequal Ecological Exchange (UEE) analysis underscores the consequences of such a system for ecosystems in vulnerable less-developed areas, such as the Brazilian Amazon (Bunker 1984; Bunker 1990). The empirical evidence of a global system of economic stratification through the mechanisms of unequal exchange that are coupled with an unequal distribution of ecological harms is readily evident in numerous studies (Bunker 1984; Bunker 1990; Jorgensen 2003; Jorgensen 2006; Jorgensen 2007; Jorgensen 2008; Jorgensen & Burns 2007; Jorgensen & Clark 2009; Rice 2007). Recently, these developments have been demonstrated for a number of wide-ranging environmental outcomes such as carbon emissions, deforestation and the pollution of water (Jorgensen 2006; Jorgensen 2007; Jorgensen 2008). One of the contradictions of these relationships is that the depressed conditions of the poor countries of the world remain despite the ever-expanding nature of the global economic system (Clark & York 2005; Dietz, Rosa, & York 2007; Jorgenson 2003; Jorgenson & Burns 2007; York 2008; York, Rosa, & Dietz 2003; York, Rosa, Dietz 2009).

Likewise, multiple empirical analyses indicate the ecological damage and unsustainable patterns of life in the north within the context of structural human ecology (York 2008; York, Rosa, & Dietz 2003; York, Rosa, Dietz 2009). The structural human ecology approach is most intimately tied to the use of the ecological footprint as a measure of overall ecological well-being and the findings on this score echo those of the ToP and UEE theory: the greatest environmental impacts stem from the most highly developed economies, these effects are global, and the impact of population and consumption are clear (York 2008; York, Rosa, & Dietz 2003; York, Rosa, Dietz 2009).

An assumption made by all of the unsustainable economic systems perspectives is that economic systems are dependent upon ecological systems for their survival and that human social systems have ecological consequences for the planet. As ecological economists have long pointed out, the economic system is a subsystem of the ecological system (Goodland & Daly 1996). With continual economic growth within a finite ecological system the results point to what O'Connor labels the "second contradiction of capitalism" (O'Connor 1998); namely, that an ecological crisis will result in "underproduction." Whereas the proponents of environmental reform argue that ecological crisis will lead to an environmentally conscious market-driven solution, the proponents of the various unsustainable economic system perspectives see inevitable environmental damage. As a consequence, human systems have arrived at an impasse that calls into question our economic philosophies of limitless growth without a change in perception of our place within the natural system. We suggest that it should be the United States that innovates; however, innovation through technology is not sufficient as education to promote a different American ideal, one that embraces a new philosophical shift, is necessary. Our goal here is to map a way forward such that we can begin to consider the means of adaptation and resilience we will need to employ as we face the consequences of global climate change. In order to do so, we focus upon "true" and "false" sustainability (Freese 1997) and how a holistic conception of sustainability is found in Holling's (1973) conception of adaptation and resilience that affords us a means to understand the intersection of socio-cultural systems with biophysical systems.

Paradigm Shift: "True" and "False" Sustainability

Many scholars have argued that the global environmental crisis results from our tendency to think and perceive in terms of a fragmentary (dualistic) paradigm (Bohm 2002; Capra 2004; Wilber 2001). This paradigm — commonly known as the Cartesian paradigm — treats as fundamental the distinction between human (cultural) and non-human (natural) systems, while assuming that each has its own independent and generally fixed essence.

The Cartesian paradigm has made extraordinary contributions to human affairs in the flourishing of Western culture, scientific endeavor and material well-being. But it has also brought with it human alienation, ecological devastation, social injustice and spiritual impoverishment. British scholar Peter Reason (2003) points out that this paradigm channels human thinking and perception in two fundamental ways. First, it tells us that the world is made of separate "things," with each thing having its own independent and generally "fixed" essence, and therefore, capable of being observed "objectively." Secondly, it tells us that human (culture) and non-human (nature) systems are disconnected (Reason 2003).

For French philosopher Pierre-Felix Guattari (2000), the maintenance of this dualistic separation between human and non-human systems, obscures the complexity of human-environment relations. For him, an appreciation of the delicately interconnected domains of environment, human subjectivity and cultural relations is crucial to understanding both the environmental crisis and the charting of alternative pathways

for a more fulfilling, just and truly sustainable future.

To reconcile the dualistic separation between human and non-human systems, Catton and Dunlap propose an environmentally-based social paradigm with the following assumptions,

- Human beings are but one species among the many that are interdependently involved in the biotic communities that shape our social life.
- Intricate linkages of cause and effect and feedback in the web of nature produce many unintended consequences from purposive human action.
- The world is finite, so there are potent physical and biological limits constraining economic growth, social progress, and other societal phenomena (Catton & Dunlap 1978, 45).

Implicit in the paradigm shift proposed by Catton and Dunlap is an ecological ethics that recognizes our interdependence with the greater web of life and our shared moral responsibility to care for life on Earth in all its diversity (Mackey 2004; Miller & Westra 2002). This ecological ethics follows from a realization that *life is fundamentally one*. The full adoption of an ecological ethics, therefore, requires abandoning our alienated, fragmented form of existence to become part of the ecological whole, to be at one with all things. The obvious implication of this ethical principle is a global society in which human beings live with a "sense of universal responsibility," identifying themselves with the whole Earth community as well as their local communities. This sense of universal responsibility can only be cultivated when we live "with reverence for the mystery of being, gratitude for the gift of life and humility regarding the human place in nature" (Brenes 2002, 29). For psychologist Abelardo Brenes (2002, 29), "this is one of the major challenges of our time, given that the current process of economic globalization is largely motivated by the insatiable desire on the part of corporate capitalism to compulsively subordinate their sense of being to the existential dimension of having *and* doing."

Embracing such a paradigm shift will force us to consider our preconceived notions and to evaluate our values and beliefs within the context of realistic assessments of sustainable social organization. In some respects, Catton and Dunlap's (1978) call for a paradigm shift has been successful, particularly within environmental sociology where there is a thriving sub-discipline. In other ways, however, there remain gaps in terms of social changes resulting in large-scale institutional changes that might result in a more sustainable world society.

The main areas of research outlined above celebrate the arrival of environmental sociology. They also, however, underscore the inability of that research to be translated into individual level or institutional level changes towards sustainable behaviors. The unsustainable economic system theories clearly demarcate the capitalist approach as one that is unsustainable; the shortcomings of environmental reform approaches have been equally demonstrated to be unsustainable (see York & Rosa 2003; York 2008). As a case in point, Jevons paradox (York 2005; York, Rosa, & Dietz 2009) illustrates the high probability that the environmental reform project is unlikely to be a long-term solution. Even if environmental reform were to result in a major transformation of our use of natural resources (e.g. use of renewable energy sources), our current trajectory appears to be that of "false" sustainability. To move towards "true" sustainability, however, will require humans to reconsider their relationship with the earth, particularly with respect to energy usage and consumption of finite natural resources, such as fossil fuels (Freese 1997).

Attempts to solve the problem of sustainability through technological transformations represent an example of "false" sustainability (Freese 1997). Although Freese's (1997) argument is directed at those endeavors to harness the power of nuclear fusion ("cold fusion") as a reliable, clean energy source for industrial societies, the argument is applicable under any condition in which human produced energy processes are decoupled from the constant source of energy from the sun. Currently, our society is dependent upon a number of such energy sources, fossil fuels being the most prominent of these resources, but the list includes coal, natural gas, and nuclear fuels. The result of such technological decoupling, Freese (1997) contends, is "false" sustainability — it provides a false sense that limits have been surpassed or are no longer applicable. Freese (1997) makes clear that the only meaningful upper limit worth considering are those imposed by solar sources of energy. Thus, any society that seeks "true" sustainability is one that relies upon solar sources of energy (1997). Within this context, the unsustainable ecological system theories are clearly based upon "false" energy sources (fossil fuels, coal, gas, nuclear), while environmental reform, at least in its current form, would also be "false" sustainability as it relies on a number of energy resources, many of which far exceed the capacity of solar sources of energy. Clearly, this is a problem tied to the laws of thermodynamics and the limits of natural resource energy supplies, yet this is also a problem of social organization as our modern, industrial societies seek ever-expanding sources of energy without any alterations in the social and cultural expectations of material conditions.

Freese's (1997) differentiation between "true" and "false" sustainability underscores the cleavage between the anthropocentric paradigms that dominate human thinking that lead to "false" notions of sustainability and the ecocen-

tric paradigms required to meet the conditions for "true" sustainability. Although we can point to incremental improvements in environmental conditions in some aspects of our ecological systems, the larger question of a sustainable way of thinking remain out of reach. It is only by considering social systems within the context of the ecosystems on which they depend can we begin to recast thinking in a manner that strives towards "true" sustainability.

Adaptation and Renewal: Our Journey Towards True Sustainability

Since the early 1970s, Holling's (1973) research on complex adaptive systems has attracted attention in disciplines ranging from anthropology to economics. More recently, Holling and his colleagues have called their theory "Panarchy theory" — after Pan, the ancient Greek god of nature (Gunderson and Holling 2002). This theory helps us to see the global social-ecological crisis as part of a long-term process of change and adaptation. It also shows us how periods of crisis could produce a surge of creativity leading to the renewal of society and avoiding ecologically unsustainable behaviors.

The significance of the Panarchy theory was the recognition that systems of human and nature, as well as coupled human-nature systems (social-ecological systems), are interlinked in never-ending adaptive cycles of growth or exploitation (r), conservation or accumulation (K), collapse or release (Ω), and renewal or reorganization (α). The arrows show the speed of the flow of events in the cycle, where short, closely spaced arrows indicate a slowly changing situation and long arrows indicate a rapidly changing situation (Gunderson & Holling, 2002).

The adaptive cycle combines the concept of growth with the process of collapse. The well-known concept of growth was that ecological systems grow from a pioneering state to a mature state (from a field to a mature forest, for example). But ecological systems can also collapse, releasing accumulated capital that can become reorganized for a renewal of the cycle. The first phase of the cycle (r -> K), often referred to as the "front loop," represents the slow, incremental phase of growth and accumulation. The second phase (Ω -> α), referred to as the "back loop," represents the rapid phase of release (or collapse of earlier control), and reorganization leading to renewal.

Three things happen simultaneously in the late part of the growth phase of any living system: the system's potential for novelty is increasing, its connectedness and self-regulation are also increasing, but its overall resilience is falling. At this point in the life of a mature forest, for example, a sudden event such as a wildfire, insect outbreak or drought can trigger the collapse of the whole system (Gunderson & Holling 2002). The results, of course, can be dramatic — the ecosystem loses species and biomass and in the process much of its connectedness and self-regulation.

But the collapse of the system liberates the ecosystem's potential for creativity and allows for novel unpredictable recombination of its components. The organisms that survive a wildfire in a mature forest, for example, become much less dependent on specific, long-established relationships with each other. The redistribution of resources allows new species to establish themselves and propagate after the fire. And because the system is far less interconnected and rigid, it becomes more resilient (Gunderson & Holling 2002).

Panarchy theory adds the idea of a hierarchy of adaptive cycles working between small (fast) and larger (slow) cycles. Adaptive cycles are nested in a hierarchy across time and space, with integrated/overlapping adaptive cycles of "revolt" and "remember." In essence, larger and slower-moving cycles provide stability and resources that buffer living systems from shocks and help them recover from collapse. Lower and fast-moving cycles are a source of novelty, experimentation and information (Gunderson & Holling 2002).

Panarchy theory identifies key variations and interactions in the grand hierarchy of social-ecological cycles. As the global social-ecological system becomes more connected, regulated, complex and efficient — and ultimately less resilient — we need ever-larger inputs of high-quality energy to maintain this complexity, overextending the growth phase of our global adaptive cycle (Homer-Dixon 2009). For Holling, the world is reaching "a stage of vulnerability that could trigger a rare and major 'pulse' of social transformation." The "rapidly rising connectivity within global systems — both economic and technological — increases the risk of collapse... that cascades across adaptive cycles — a kind of pancaking implosion of the entire system as higher-level adaptive cycles collapse, causing progressive collapse at lower levels" (Homer-Dixon 2009, 15).

The longer a system is "locked in" to its growth phase, says Holling, "the greater its vulnerability and the bigger and more dramatic its collapse will be." He urges us to do what we can to "avoid deep collapse" in "this moment of great volatility and instability in the world system." He writes, "The only way to approach such a period, in which uncertainty is very large and one cannot predict what the future holds, is not to predict, but to experiment and act inventively and exuberantly via diverse adventures in living" (Homer-Dixon 2009, 15).

Holling's panarchic system is important in two ways. First, it closely resembles the complex, interconnected set of social-ecological problems embedded within a system reflective of "false" sustainability (Freese, 1997). Second, such a scenario points to an opportunity — an opportunity to at-

tempt new ways of thinking, new means of considering human-environmental relations, and paves the way for a paradigm shift. Although elements of the old structure will remain in place, the possibilities for innovation afford the ability to reconfigure these relationships into a more sustainable, socially and economically equal, and permanent worldview; thus, we are afforded a window into a truly sustainable, equitable and ecologically-grounded society.

Conclusion

The line of reasoning we have laid out here is grounded in sociological thought, but it moves beyond sociological perspectives by embracing concepts of adaptive complex systems as a mechanism for a new, emergent social-ecological worldview. Because much of the mitigation and adaptation literature lacks the social scientist perspective, we have underscored the importance of the insights from these disciplines, particularly the contributions of critical sociological thought and complex systems theory. We couple these disciplines by arguing that "true" sustainability provides an opportunity to recast notions of paradigm shift within the context of Holling's panarchy theory. Taken together, this illustrates a way to understand our current circumstances, while pointing to our panarchic future as an opportunity for human societies to begin to emerge anew, recasting more holistic social-ecological worldviews that can lead us to "true" sustainability.

We recognize that the paradigm shift we have laid out here is a long-term process. It is possible that there is not enough time to implement these pathways to "true" sustainability, but that leaves two possibilities. If there is enough time to cultivate a new worldview then initiating educational priorities to reorient worldviews will need to take priority. We believe that only through a combination of structured and individual level prophylactics and adaptive maneuvers can such a process take hold. However, if the pace of climate change does not allow time for such efforts and the most severe effects of social-ecological breakdown begin, on some level, within the 21st century such a change in the societal-ecosystem dynamic will afford the opportunity for a new paradigm to emerge. Only by starting down this pathway now can we increase the likelihood of success.

We believe that the basis for social change lies in the holistic approach embedded in the emerging field of complexity theory as exemplified in the work of C. S. Holling and his colleagues. Holling's theory of adaptive cycles has made significant contributions to our understanding of change in complex, coupled social-ecological systems. The relevance of Holling's theory is the recognition that changes in social and ecological systems occur in hierarchical adaptive cycles (Panarchy). The most novel and significant aspect of this theory concerns the "back loop" phase of the adaptive cycle where resisting structures and institutions start to break-down or transform, releasing the opportunity for a renewed system to emerge. Unstable food prices, oil dependencies, financial disruption, social injustice, ecological devastation, and climate change are all indicators of decline in the global social-ecological system. From a perspective of the Panarchy theory, there is now a great need to free ourselves from the structures that block innovation, from our attempts to stabilize those structures, and encourage small-scale experiments, which from a complex systems perspective, can trigger large scale changes that can leads to a truly socially just and ecologically sustainable future.

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Endnote

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