World-Systems as Complex Human Ecosystems

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Reflecting on the impressive breadth of perspective that has been applied to the study of world-systems, Straussfogel (2000:169) recently observed, "Perhaps a little ironically, the only way world-systems have not been much considered is as a *system*." She proceeds to advocate "dissipative structures" theory (Prigogine & Stengers 1984) and the revolutionary systems thinking that it engenders for "open" natural systems including world-systems. From this perspective, the relationship between world-systems and the environment is forced to center stage: "Seen as a multileveled complex system exhibiting the properties of a dissipative structure, the [world-] system-environment relationship looms as crucial" (Straussfogel 2000:175). This chapter takes up the important challenge of furthering the integration of world-systems theory with environmental and complex systems science.

World-systems can be productively conceived as complex systems: complex human ecosystems. Complex systems are a general class of phenomena found ubiquitously in nature. While definitions vary, complex systems can be described as open, dissipative structures that self-organize into forms that are multi-scaled and hierarchical, that exhibit emergent properties, that make use of information at many scales from genes to culture, and that exhibit complex dynamics of pulse and collapse, discontinuous change or "surprise," and nonlinearity, leading to multiple stable states.

World-systems, comprising core, semiperiphery, and periphery, are by definition multi-scaled and hierarchical structures. Conceptualized as "complex human ecosystems" (Abel & Stepp 2003), world-systems are material and energetic self-organizing systems that are multiple-scaled in *space* and bounded in *time*, exhibiting complex dynamics that includes pulse, collapse, cycle, and chaos. As ecosystems, they are spatial entities that capture and use energy

and materials, structured by information from many scales. As complex systems they are self-organizing phenomena with emergent properties. As "human ecosystems," they are dominated by the material assets, social organization, and cultural models at their disposal.

Since its conception (Wallerstein 1974), the world-system concept has inspired research and generated debate. Wallerstein's original model was of a multi-state system of capitalist countries bounded in space and time, with a division of labor and trade relations that favored a core of one or several nations over a surrounding periphery of other nations. Since that time there have been efforts to extend the model back in time to precapitalist social formations (Abu-Lughod 1989; Chase-Dunn & Hall 1995, 1997; Frank & Gills 1992). There has been interest in redefining its boundaries politically (Modelski 1987), symbolically (trade in luxury goods) (Schneider 1977), and otherwise. Some have sought to compare and possibly combine it with the concept of "civilization" (Wilkinson 1995). This chapter covers such definitional debates and proposes a complex human ecosystems definition of world-systems. This definition of world-systems has implications for understanding sociocultural cycles as well as the larger process of cultural evolution, and this chapter explores these implications.

Ecosystems as Complex Systems

Pickett and Cadenasso (2002:2), following Odum (1959), following Tansley (1935), define an ecosystem very flexibly as "any size so long as organisms, physical environment, and interactions can exist within it. Given this . . . ecosystems can be as small as a patch of soil supporting plants and microbes; or as large as the entire biosphere of the Earth. However, all instances of ecosystems have an explicit spatial extent. The extent must be specified and bounded." They proceed to fully explore the ecosystem as a concept, model, and metaphor. Of special interest for my discussion at this point is the "spatial" feature of this definition. An ecosystem boundary, at whatever size determined by the analyst, is not placed around an animal, plant, or human institution such as government or economy. An ecosystem, in "all instances," is an explicitly spatial entity, a physical space on Earth that encompasses interacting biotic and abiotic complexes, a location "as small as a patch of soil . . . or as large as the entire biosphere."

There is a simple reason why the ecosystem is a spatial concept. Ecosystems are open energetic systems that exist on Earth because energy flows through them, energy from lunar gravity, from Earth deep heat, and especially from the sun. When these energies reach the Earth's surface they interact with living organisms and nonliving substrates, self-organizing into the structures and processes of an ecosystem. Ecosystems are thus spatial entities, constructed by the convergence of energies at or near the Earth's surface.

Simon Levin (1998:431) characterizes ecosystems as "prototypical examples of complex adaptive systems." Self-organization divides natural systems into multiple temporal and spatial scales. A product of maximizing energy dissipation, nature is conceived to be discontinuous across scales, forming lumps or wholes in nested hierarchies (Holling, Gunderson, & Peterson 2002:77–88). Ecosystems are nested within the biosphere, while simultaneously composed of nested scales selected by biological, chemical, and physical processes.

Natural, open, self-organizing ecosystems are not static in time but exhibit fluctuations, both regular and unpredictable. Ecosystems are thought to be sometimes more and sometimes less resilient to perturbations, and for reasons that are difficult to predict. Fluctuations from small or large scales, both internal and external to the ecosystem, can lead to transformations. The pulsing or fluctuations of ecosystems is now felt to be a common property of complex systems, most thoroughly explored as an "adaptive cycle" by Holling (1987; cf. Figure 8). Ecosystems, like other complex systems, are thus multi-scaled, hierarchical, self-organizing systems that exhibit fluctuations in both time and space.

Complex Human Ecosystems

A "human ecosystem" is depicted with a systems diagram in Figure 1 (Abel 2003; Abel & Stepp 2003).[1] The sun is the most important energy source for ecosystems, delivering gravitational and solar energy and creating weather, wind, rain, and seasonal fluctuations, although lunar gravity (tide) and Earth deep heat (uplift) are other essential sources (see the circle on the left) (Odum 1996). Gradients of sunlight and fluctuating patterns of wind and rain have had defining impacts, it now appears, on the pulsing growth and collapse of human ecosystems, including world-systems (de Menocal 2001; Gill 2000; Weiss & Bradley 2001). These impacts will be discussed below along with other temporal dynamics of world-systems.

Concentrations (of energy, materials, structure, and information) within a human ecosystem include natural resources and sociocultural storages ("storage" tanks, Figure 1). Natural resources in Earth systems are commonly partitioned into categories of "renewable" (sun, tide, uplift), "slow-renewable" (timber, topsoil, groundwater), and "nonrenewable" (coal, oil, natural gas, metals) resources. This categorization scheme is based on the turnover time

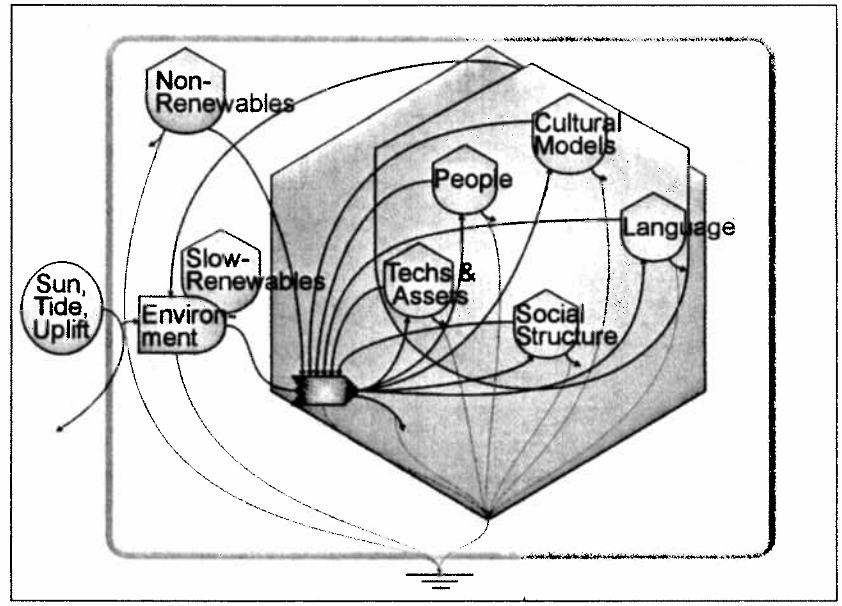

Figure 1 • Human ecosystem. A human ecosystem is spatially defined to include energy inputs, a physical substrate ("a patch of soil"), natural resource storages ("storage" tanks), and a human sociocultural system. A sociocultural system is a general term that applies to aggregates of humans at any scale, from foragers to chiefdoms, archaic states, modern states, and world-systems. The ecosystem context of the sociocultural system is represented in highly aggregated form to the left in the diagram. Important sociocultural storages are shown and discussed in the text.

relative to human life spans. For example, coal or oil, while renewable on the timescale of geological processes, are *non*renewable at the scale of people or even civilizations. A convincing model of a sociocultural system should include "storages" of material assets, social structure, cultural models, and language, as well as the interactions between these components, the natural environment, and the people that continuously produce and renegotiate their forms (Abel 2003). These components always co-occur, with none occurring before another.

A point to emphasize is that no storages are static—that is, not population, technologies, assets, topsoil, groundwater, social structure, or any other such factors. Even when a system appears to be changing very little, its storages are depreciating and must be replenished. This fundamental principle of nature is called the Second Law of Thermodynamics, or "Time's Arrow" (Prigogine &

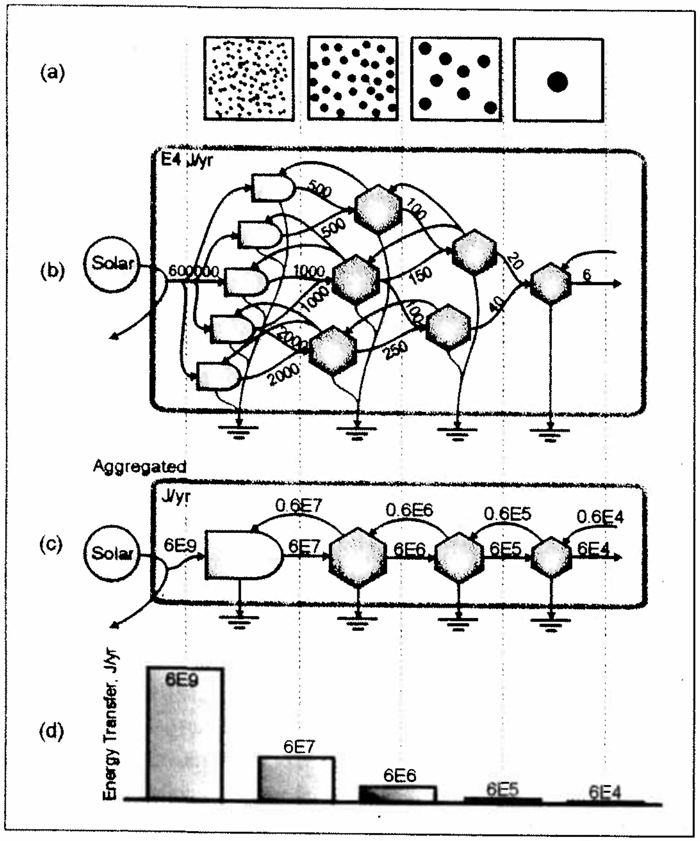

Figure 2 • Energy transformation hierarchy (adapted from Odum 1996:23). (a) Spatial view of units and territories; (b) energy network including transformation and feedback; (c) aggregation of energy networks into an energy chain; (d) bar graph of energy flows for the levels in an energy hierarchy. It is a principle of systems science (Odum 1996) that open systems, such as ecosystems, are non-equilibrium thermodynamic systems that self-organize into energy transformation hierarchies. Figure 2 depicts a hierarchy from four different perspectives. Figure 2b shows a typical hierarchy that could be an ecosystem with plant producers on the left and animal consumers on the right, concentrating food in a food web that is capped by one or several top carnivores. The energy that moves through that web is highlighted in the Figure 2d bar graph, with energy amounts shrinking as they move through the web.

Stengers 1984). In Figure 1, both the sociocultural system configuration and the environmental inputs are dynamic, constantly forming and reforming in the energy flux of an open natural system. Both culture and nature are highly dynamic, neither being merely the static backdrop for the other.

Complex human ecosystems can be redrawn in a form that displays the structural hierarchy within. Figure 2 depicts Odum's hierarchy of energy transformations, ubiquitous in self-organizing complex systems, illustrating Odum's (1996:16) proposed Fifth Law of Thermodynamics. An ecosystem is an obvious example, in which solar energy is converted to plant and animal biomass in hierarchical food webs, depicted in Figure 2b. At each step in a hierarchy, energy is lost as concentrations are made into species with "emergent" properties (complex proteins, mobility, landscape builders). Figure 2c is an aggregated diagram of Figure 2b, which emphasizes the energy transformations and reduces and consolidates the complexity into a visually simpler form.

Figure 1 can be redrawn, as in Figure 2b-c, by replacing the single "social structure" storage with an energy transformation hierarchy (Abel 2003). This diagramming convention can be applied to any human ecosystem and will be used in the world-systems diagram below (Figure 5).

World-Systems in Space

With this conceptual background, world-systems will now be discussed as complex human ecosystems, bounded in space and time. As far as we know, our universe is one single universe. Energy impinges on the Earth from far reaches and near. One biosphere, not more, envelops our globe. There are no boundaries in nature. Yet there are discontinuities. It is argued that self-organization leads to gradients (Wicken 1987), that nature forms lumps or wholes in nested hierarchies, as was just described (see also Holling, Gunderson, & Peterson 2002:77–88). In theory, a scientist can draw a boundary around anything he or she wants to study. In practice, however, it is more convenient to take advantage of the discontinuities in nature. Physiologists do not normally divide a person in half but rather make use of the (permeable) natural boundary of our skin.

Ecosystem scientists also seek discontinuities in defining a unit of study. One such common unit is a watershed. Within a watershed there are countless pathways of energy and material flows. Certainly animals and seeds cross watershed boundaries, but because so much physical, chemical, and biological work in ecosystems is done by rainfall there exists a gradient or discontinuity along the edge of natural drainage, that is, along the watershed "boundary." Another example is an island ecosystem, which might be bounded by its

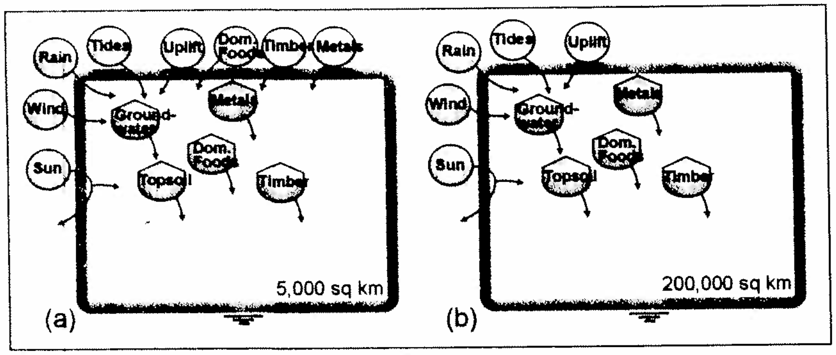

Figure 3 • Boundaries of early modern world-systems. Two options for boundaries around an early modern world-system. Note that these two drawings show only sources and storages and omit any flows or interactions, as were depicted in the previous diagrams. The focus here is boundaries, and not internal structure.

shoreline but is more logically defined to include the near-shore production of reefs or estuaries, down to the effective limits of sunlight. The biosphere as a whole is the largest scale for life on Earth. But nested within it is a hierarchy of self-organizing systems, from ecosystems to chemical cycles.

A number of researchers have attempted to define the boundaries of world-systems. Christopher Chase-Dunn and Thomas Hall have summarized and grouped the different conceptualizations of world-system boundaries into four categories (Chase-Dunn & Hall 1995, 1998). Some argue that trade in prestige goods is the largest important interaction network for world-systems and should therefore constitute its spatial limit (Schneider 1977). Chase-Dunn and Hall label this model "prestige goods exchange network (PGN)." Others believe that military alliances among a group of states in regions defines the world system (Wilkinson 1987), what Chase-Dunn and Hall call "political/military interaction networks (PMNs)." The most inclusive world-system boundary they define is a social network, called the "information exchange network (IN)." The most restricted world-systems boundary, which they call the "bulk goods exchange network (BGN)," coincides with Wallerstein's original formulation for world-systems, which focuses on trade in primary commodities.

A complex human ecosystem model of world-systems would focus on gradients in the flows of essential energies, natural resources, domesticated foods, or minerals, roughly equivalent to the BGN model. These are the necessary material foundations of any human ecosystem and sociocultural system within it. Once included, this ecosystem scale contains the necessary and sufficient

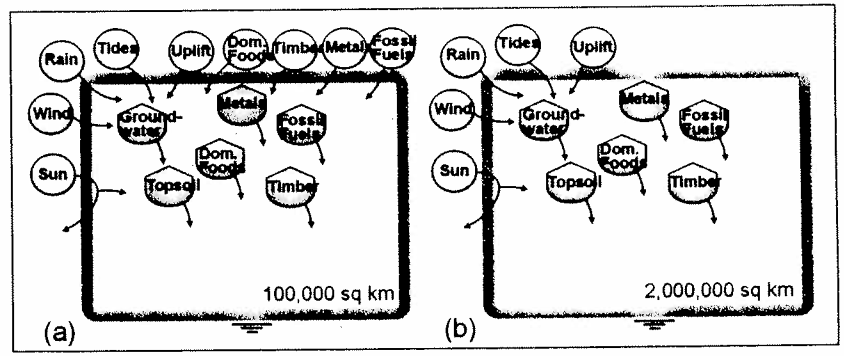

Figure 4 • Boundaries of contemporary world-systems. Distinguishing Figure 4 from Figure 3 is the addition of "Fossil Fuel" sources and storages. Fossil fuels are such an important addition to the provisioning of contemporary world-systems that they deserve special distinction.

ingredients for self-organization of the multi-scaled world-system structure.

These considerations support Wallerstein's formulation of the BGN model because of its spatial and material orientation, which can productively articulate with ecosystems and complex systems theory. Furthermore, this design compensates for an omission in the typologies of cultural evolution in anthropology, viz. a category for extra-state social formations, a level more inclusive and qualitatively different than archaic states or empires.

Figure 3 depicts two models of an early modern world-system. The "Golden Age" Dutch world-system of the seventeenth century is an example (Wallerstein 1974). In Figure 3a, a boundary is drawn around Holland. Within that boundary, important storages supporting the human sociocultural system include surface and ground water, topsoil, peat, domesticated food production, some timber, and mining. However, the Golden Age Dutch world-system depended on timber from Scandinavia, grain from the European heartland, and other key inputs such as salt from the southern Caribbean. From a human ecosystems perspective, the boundary of the Dutch world-system is thus better drawn around those bulk-goods-producing regions as peripheries, feeding natural resources to the Holland core. Figure 3b therefore draws the boundary just wide enough to reduce the flows of essential goods across its border by expanding it to include the resource-producing regions.

Figure 4 is a model of contemporary world-systems that is similar to Figure 3. Figure 4a includes a "too small" world-system boundary with inputs of primary commodities of domesticated foods, timber, metals, and fossil fuels.

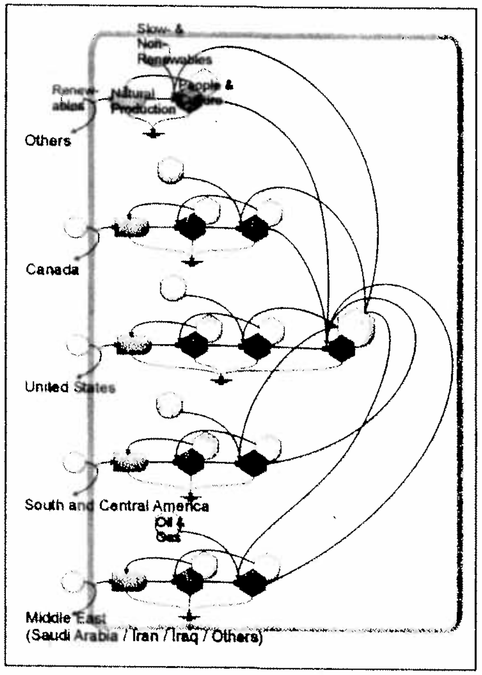

Figure 5 • A "Cold War" world-system with a U.S. core. A modern capitalist world-system of nations defined by bulk-goods trade unequally forming the core, which can be measured in ecological-economic terms (see Abel 2003).

Figure 4b represents a more inclusive boundary. This design has implications for defining twentieth-century world-systems. By this account, the last century would have begun with perhaps three world-systems, a dominant European-centered system, a U.S.-centered system, and a Japan-centered system. The Cold War world witnessed the expansion of a Soviet-centered system and decline of the Japan-centered system (Figure 5 depicts the U.S.-centered system). Note also that countries or regions may at times fall outside any world-system, as did China and Indonesia after the collapse of the Japan system and the contraction of the European system after World War II.

Figure 5 is a world-system conceived spatially and located in time. It is a multinational division of labor organized by trade flows. Note especially that each nation is represented in human ecosystem terms, as a spatial entity constructed "from the ground up," with energy sources and local storages of natural resources, all supporting a sociocultural hierarchy (compare to Figure 2c). The nations are then joined together by trade flows into a world-system. The innovation of the world-system is that it creates a larger spatial scale and thus a greater area for energy convergence.

By this conceptualization, today there is a single hegemonic U.S.-E.U.-Japan world-system, though China may be in the center of an emergent new

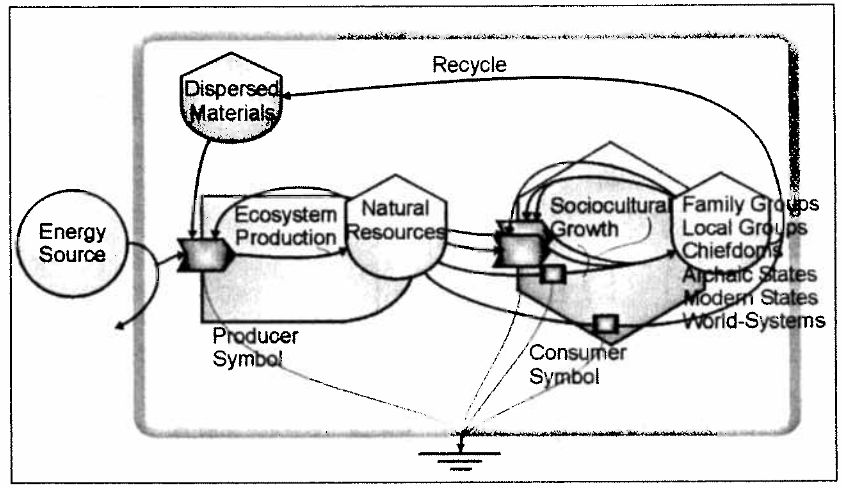

Figure 6 • Pulsing sociocultural systems. Coupled producers-consumers with recycling can be a pulsing organization. The storages have different spatial and temporal scales (Odum & Pinkerton 1955).

system. Yet considering the slow growth of global energies, the world future more likely holds for us decomposition of the existing world-system, the end of a "secular cycle," rather than composition of new systems (Abel 2000:414–428). This is explained in the next section.

World-Systems in Time: Storages and Pulsing

In dissipative structures theory, when an energy gradient exists between a storage and a sink, or between a source and a sink, self-organization occurs that has the effect of hastening the dissipation of energy (Prigogine & Stengers 1984). The process of self-organization is inherent in the thermodynamics of inorganic and organic matter and energy. Energy dissipation is revealed to be a highly creative process.

Self-organization often leads to pulsing patterns, the building of energetic storages followed by their autocatalytic consumption and dissipation, depicted in Figures 6–8 (Odum & Pinkerton 1955; Holling 1987). In Figure 6, the system of multi-scaled self-organization is a pulsing system that produces the cycle in Figure 7. Examples include fire-controlled ecosystems, locust outbreaks, or cross-catalytic chemical reactions. It is expected that this pulsing pattern would also be observed with storages used by humans. It is well known that small farmers who use slash-and-burn techniques occupy an area only

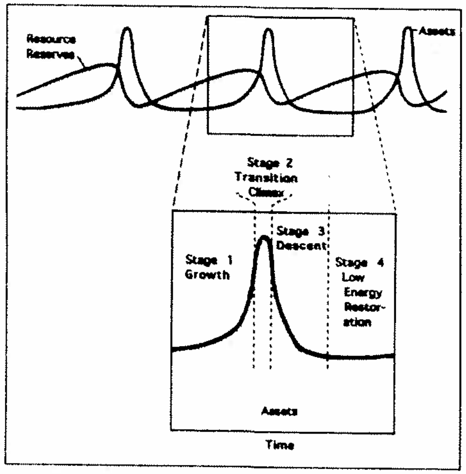

Figure 7 • Pulsing. Typical cycle in which pulsing of consumer assets alternates with productive restoration of resources. Four stages are defined to aid discussion (from Odum and Odum 2001:78, reprinted with permission).

long enough to consume the storages of nutrients; then they move on. In more complex human systems such as chiefdoms or archaic states, pulse and collapse have been observed, as in ancient Greece (Runnels 1995), the Maya of Yucatán (Culbert 1988), and the Roman Empire (Perlin 1991). In the world-systems literature, there is growing interest in this pulsing and collapsing of sociocultural systems and their human ecosystems at different scales (Bosworth 1995; Chase-Dunn & Hall 1998; Frank 1995). So-called civilizations such as the Andean or the Chinese are better conceived as systems repeatedly pulsing and collapsing in space and time (Marcus 1998; Wallerstein 1995).

Perhaps the best known pulsing and cycling model today is the "Adaptive Cycle" proposed by Holling (1987), a general pattern with four phases: exploitation, conservation, crisis/release, and reorganization. Odum's pulsing model fits this pattern (Odum & Odum 2001), as do other cycling models (Figure 8).

In complex human ecosystems, cycles are nested, as in Figure 9. Figure 9 gives only an indication of the complex pattern of nested scales of pulse and collapse that exist in open systems in nature. Not surprisingly, the history and prehistory of humans and human ecosystems has been complex, filled with pulse and collapse of whole systems or parts of them. For world-systems, collapse does not mean the disappearance of peoples or nations but rather the decomposition of core-periphery bulk trade networks and the return to single state-scale organization or, in the peripheries especially, decomposition into even smaller-scaled social formations resembling chiefdoms, located within the political shells of nation states (as today in Somalia, the Ivory Coast, Burundi, and so on).

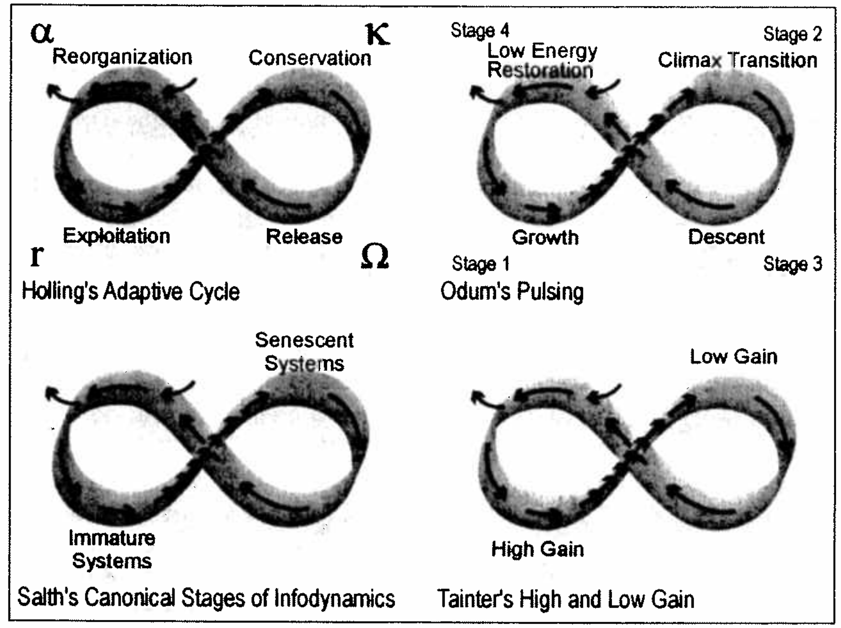

Figure 8 • Cycles in complex systems. The "Adaptive Cycle" has been extensively discussed and elaborated (Gunderson & Holling 2002; Gunderson, Holling, & Light 1995). Odum has emphasized a similar model of growth, transition, descent, and low energy restoration, a design which he contends maximizes self-reinforcing energy flows in many systems (Odum & Odum 2001; Odum & Pinkerton 1995). His model does not have the resolution of detail into important mechanisms of release and reorganization that Holling's does. Salthe's (2003) model of canonical stages of infodynamics is another cycling model, as is the High Gain/Low Gain model of Tainter and colleagues (2003).

Implications for World-Systems Theory

World-systems theory thus reconceived has implications for some unsettled issues. Two of particular interest to other world-systems theorists are explored below, suggesting both the promise and the novelty of viewing world-systems as complex human ecosystems.

Cycles in Sociocultural Systems

Cycles have captured the attention of world-systems research in recent years. Here I consider three often-studied cycle types. "Kondratieff cycles" (K-waves) have been much discussed (Frank 1995; Straussfogel 2000; Thompson 2000).

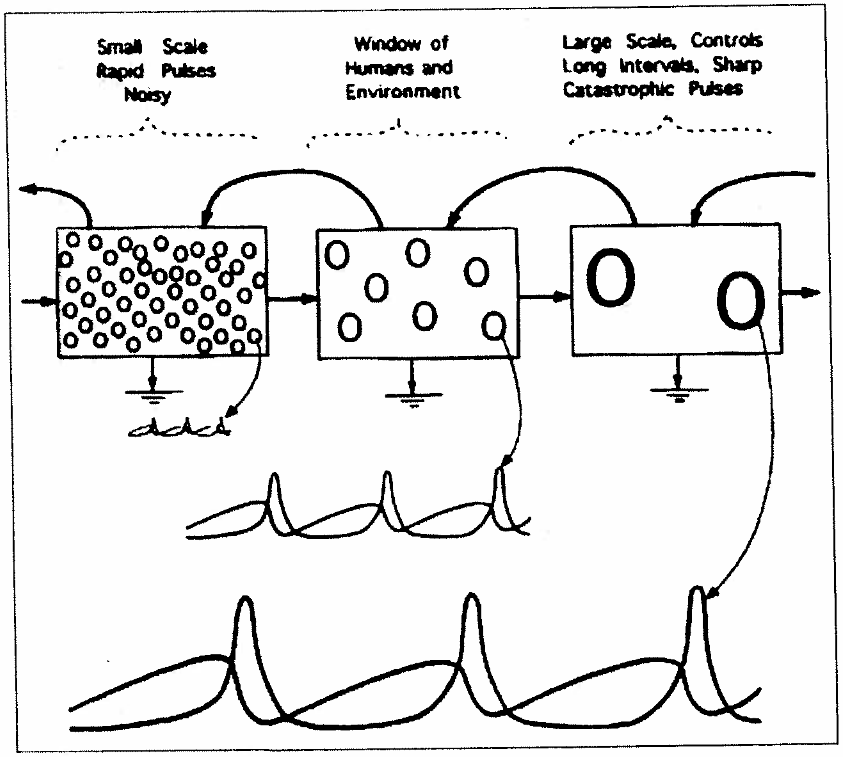

Figure 9 • Pulsing at multiple scales of space and time. Sketch showing the pulsing for three scales of time and space. Larger scales have sharper pulses and longer interpulse periods. Many nested cycles are conceivable for the biosphere (from Odum and Odum 2001:82, reprinted with permission).

As Turchin and Hall (2003:39) explain: "The basic dynamic is that a new technology allows economic expansion. Eventually the market saturates, and competition increases, and the expansion slows until another cycle, based on yet another new or renewed technology, develops."

In terms of Figure 1, a new technology is equivalent to expanding the storage of "Assets and Technologies," which would recursively amplify the capture of more natural resources, resulting in "economic expansion." In addition, because all sociocultural storages are linked, the other storages will grow, including population, social structure (division of labor), cultural models, and even language (that is, adding new vocabulary, or— if the growth is sustained enough for the sociocultural system to expand its reach spatially—expanding the language hegemony, as English has expanded its reach and varieties today[2]).

It does not suffice to explain the contraction of a K-wave, however, in terms of "the market saturates, and competition increases." In a complex human ecosystem there are real physical limits that always restrain growth, here represented by limits to nonrenewable resources (oil, coal, metals), but also to slow-renewables such as timber or groundwater, or full renewables such as agricultural produce. Furthermore, within the interconnected sociocultural system, real economic growth eventually leads to growth of *all* storages (as just explained)—population growth, division of labor, cultural models—which also draw on resources and which hasten the restricting effect of physical resource limits. Resource limits from any of many scales, plus the burden of maintenance of all interrelated cultural storages, including the new division of labor, new cultural models, and so on, together contribute to the decline phase of the K-wave.

A special consideration for recent cycles is that economic growth during the last 150 years has been riding the fossil fuel wave, which has clouded our collective view of natural limits (and fueled a global population explosion) by providing energy for real growth in all sectors. This has given us the false impression that economic expansion can occur whenever technological innovations appear. From the longer history of technological innovations, we know this to be untrue. The "new technology" that starts a cycle must appear at a time when necessary storages are available from many spatial and temporal scales of humanity and the environment, including all the necessary natural resources plus an appropriate division of labor, possessing the necessary cultural models and language skills.

"Hegemonic cycles" are the century-long cycles "in which one state in a core dominates a world-system through economic and political power, typically without overt coercion" (Turchin & Hall 2003:39). A hegemonic cycle, therefore, refers to the expansion and contraction of an explicitly bounded spatial entity (a world-system). This cycle, however, can again be explained with reference to resource limits. First, the logic of spatial expansion is understandable as the means to capture untapped resource storages in virgin forests, topsoil, and mineral deposits. This leads to sociocultural system expansion as a whole, with its many requirements for maintenance. As resource storages are consumed unsustainably, especially the slow-renewables timber and topsoil with turnover times of 50–200 years, and the maintenance of world-system organization remains high, the system reaches a point of instability and contracts.

"Secular cycles," that is, "periodic waves of state breakdown accompanied by oscillations in population numbers" (Turchin & Hall 2003:39), by this account are the same phenomenon. In other words, by explaining hegemonic cycles human-ecologically instead of as the result of "power" fluctuations, I am proposing a model of macro-scale dynamics for sociocultural systems.

Where this explanation differs from many others is in its account of a highly dynamic and pulsing environment, a complex interconnected human presence often stressed by its own weight of numbers, and fluctuating boundaries of the human ecosystem and its associated resources. Because sociocultural systems always occur within human ecosystems, *space* is a fundamental factor in understanding all components and their dynamics in time. Archeological and ethnographic evidence tells us that spatial fluctuation is the rule, not the exception for sociocultural systems. Only with the relatively recent advent of fixed nation-state boundaries have human ecosystem boundaries ever been stable for long. And that stability was perhaps a short interlude, for world-systems theory would contend that actual human ecosystem boundaries have become both larger-than-states and fluctuating.

Evolution in Sociocultural Systems

This complex human ecosystems model has many implications for the long tradition of cultural evolutionary theory in anthropology (Carneiro 1970; Flannery 1972; Harris 1977; Johnson & Earle 1987; Morgan 1877; Service 1975; Spencer 1860; Steward 1955; White 1959), which has recently generated much interest among world-systems researchers (Chase-Dunn & Hall 1998; Sanderson 1990). I will raise only two issues regarding the subject that can illuminate my definition of complex human ecosystems (see Abel 1998 and Abel 2000:341–428 for further discussion).

First, in Figure 1, we can see that the source of culture change is not restricted to single "prime movers" such as "population pressure" or its predecessor "technological progress." In fact, characterizing any but the earliest cultural evolution theory as linear or driven by "prime movers" is an over-simplification of what was already recognized in its day as a highly systemic process (Carneiro 1970; Flannery 1972; Harris 1977). More recent accounts from anthropology (for instance, Johnson & Earle 1987) and world-systems (Chase-Dunn & Hall 1998; Sanderson 1990) have become more overtly systematic. For example, Chase-Dunn and Hall's dynamic "iteration model" accounts for many interrelated variables in the process of cultural evolution: technological change, population growth, intensification, environmental degradation, population pressure, emigration, circumscription, conflict, and hierarchy formation.

Cultural evolution conceived in terms of the complex human ecosystems model is an emphatically systematic account. Change in open self-organizing systems is expected, incessant, and directional, owing to the teleomatics of energy dissipation (Prigogine & Stengers 1984). A sociocultural system is conceived as a self-organizing system of amplification, constraint, and pulsing dynamics with many shifting limiting factors within ecosystems and within itself (population density being only one). For instance, sociocultural complexification may be simultaneously pushed (for example, by population pressure), pulled (for instance, by agricultural innovation), squeezed (for example, by approaching water limits, topsoil depletion, spatial contraction due to warfare, and so on), collapsed (for instance, by geologic pulses such as volcanoes, weather pulses such as large-scale hurricanes, climate change, loss of resilience, and so forth), in more ways than I can list.

Chase-Dunn and Hall's "iterative" model is a better approximation of this, although it emphasizes the "push" of population pressure and offers only an unelaborated environment with incomplete dynamics and theorizing of its own. Within the material constraints of a dynamic environment and model of production should be situated the human symbolic systems of cultural models, which have structures and dynamics of their own. Intentionality and agency can be understood to self-organize with a highly dynamic human and extra-human environment. This complex nexus of human ecosystem causality is what is represented by a simplifying systems diagram such as the one in Figure 1.

Second, there has been much discussion in the world-systems literature about extending the concept back in time to include precapitalist social formations that anthropologists have called bands, tribes, chiefdoms, and archaic states (Harris 1977; Johnson & Earle 1987). The point has been made, for example, that capital accumulation, a determinant characteristic of the modern world-system, has precapitalist roots in early states (Ekholm & Friedman 1982), and has perhaps "*always* been a driving force of world development" (Gills 1995:137).

I would prefer to see this initiative turned on its head. Considered in terms of the human ecosystems model (Figure 1), the autocatalytic structure of capitalist accumulation is unsurprisingly pervasive in human social formations, as it is in nature generally. Rather than applying Wallerstein's world-systems model, which is a useful referent to specific capitalist multistate entities, back in time to all social formations, I would argue for reserving that term as it is, and adopting a more general term, that is, complex human ecosystems, which encodes a general model of structure, function, and complex dynamics.

Conclusions

World-systems theory can be enriched by a close relationship with ecosystems and complex systems theory more generally. The history and prehistory of humans and human ecosystems take on a radically different appearance when conceived in terms of systems of energy and their complex transformations.

Permanence is replaced by flow, fluctuation, and cycling. Space becomes a dynamic and critical dependent variable.

Rather than extend the concept of world-systems to encompass "kin-based" foragers, local groups, chiefdoms, or archaic states (including empires), I argue instead that it is more useful to maintain these distinct terms. The "world-system" concept has a place in this typology of social formations. It has served well to uncloak nationalist ideologies and reveal the system connections *between* nations that have real and often oppressive effects.

To call everything a world-system is to dilute the concept of its analytical strength. I do not believe that my world-systems model is more "correct" than that of the prehistorians or civilizationists. Intriguing properties of "cycling," inequality, hierarchy, and spatial scales should be expected and can be found in social formations generally. However, general processes deserve a general name, such as human ecosystems. Calling them all world-systems subtracts from the usefulness of the concept, which is its final measure of success.

How does this complex human ecosystems model differ from other models of cultural evolution or world-system formation? It emphasizes that the "environment" is a "moving target," not a permanent stage for the human play. It defines world-systems in space and time. It expects to find pulse and collapse, and at multiple temporal and spatial scales. And it locates world-systems in a natural world, a dynamic open system with material and energetic limits that must be considered in any account of our history or future.

Notes

1. This paper applies many of the conventions developed by H. T. Odum to understand and depict ecosystems and complex systems. The work of H. T. Odum spanned systems of all types. In forty years of active research, he and his brother E. P. Odum helped define the modern field of ecology. In the last fifteen years, his work was rediscovered by complex systems scientists (for example, Depew & Weber 1995; Van de Vijver, Salthe, & Delpos 1998). What makes it complex systems science? In brief, much of his research focused on the self-organization of natural, open, thermodynamic systems that creatively build themselves and dissipate energy (Odum 1983; Odum 1988; Odum 1995; Odum & Pinkerton 1955), systems sometimes called "dissipative structures" (Prigogine & Stengers 1984). Other complex systems domains of his work are (1) autocatalytic, nonlinear dynamics, (2) pulsing or chaotic systems (Odum & Pinkerton 1955), (3) hierarchy (Odum & Odum 2001), and (4) scale (Hall 1995). In recent years this work directly led him and colleagues to the creation of a form of ecological economics called "emergy" accounting (Odum 1996; Odum, Odum, & Brown 1998). Emergy accounting has been used to evaluate sustainability (Odum 1994), international trade equity (Odum & Arding 1991), and global forecasting (Odum & Odum 2001).

2. With the most dynamic economy and often the largest military, the hegemon also disseminates its language, culture, and economy as "global" standards (Grimes 2000:47).