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Synthesis

Remarkable Properties of Human Ecosystems

John Richard Stepp[1], Eric C. Jones[2], Mitchell Pavao-Zuckerman[2], David Casagrande[3], and Rebecca K. Zarger[4]

ABSTRACT. This paper explores some of the remarkable properties that set human ecosystems apart from nonhuman ecosystems. The identification of these properties provides a framework for bridging the theoretical and methodological divide between biological ecology and human ecology. The unique information-processing capability of humans in ecosystems is central to this framework. We discuss several manifestations of human cognitive and behavioral abilities, termed "remarkable properties" of human ecosystems. A cross-cultural and historical approach is taken in demonstrating some of these properties. Related to these properties are the ways in which complex functional and dysfunctional or maladaptive processes take place in human ecosystems. We assert that one of the greatest challenges for human ecology is to integrate belief systems as a major component of human ecosystems.

INTRODUCTION

The objective of this article is to present some of the properties of human ecosystems that set them apart from nonhuman ecosystems. We strive to establish an anthropological understanding of human ecosystems, drawing upon holistic efforts to understand human cultural, i.e. nonbiological, variation and change by using the compositional techniques and scholastic background of more mature ecological disciplines (Stepp 1999, Kuchka 2001).

We use the term "human ecosystem" to refer to human-dominated ecosystems in which the human species is a central agent (Vitousek and Mooney 1997). A case could be made that the whole planet is a human ecosystem, in that all earth ecosystems have been influenced by humans (cf. Vernadsky 1945, Tielhard de Chardin 1959, Salthe 1993, Wyndham 2000). However, although the boundaries may at times be fuzzy, there are differences between conceptualizations of human ecosystems and nonhuman ecosystems. Certainly, there are properties of human ecosystems that are not found in nonhuman ecosystems. Although these properties may not always be entirely unique, they are operationally different enough to set them apart. Their influence on nonhuman systems also merits special attention, and they must be considered in the development of a truly integrated ecology that deals with the biophysical systems on our planet. In part then, this paper is an appeal for a more integrative ecology, which may be able to more fully address present and future crises for both human and nonhuman ecosystems.

We propose here that anthropologists cannot understand the human condition without contributions from biological ecology, especially the integrative aspects noted by Holling (1998). Conversely, an anthropological perspective is necessary if biological ecologists are to understand human ecosystems. Thus, without a sustained and concerted effort at interdisciplinary integration we will surely fail in our attempt to understand human ecology at the level of ecosystems.

The gap between biological ecology and human ecology is mainly the result of past failures to include relevant information and sociocultural systems in biological ecosystem models concerned with energetics and material cycles. Thus, we first present an example of an inclusive and far-reaching conceptualization of nonhuman ecosystems, then proceed to a conceptual model of human ecosystems that lays the foundation for a discussion of the role of information in human ecosystems as a way of bridging the gap between human ecology and biological ecology.

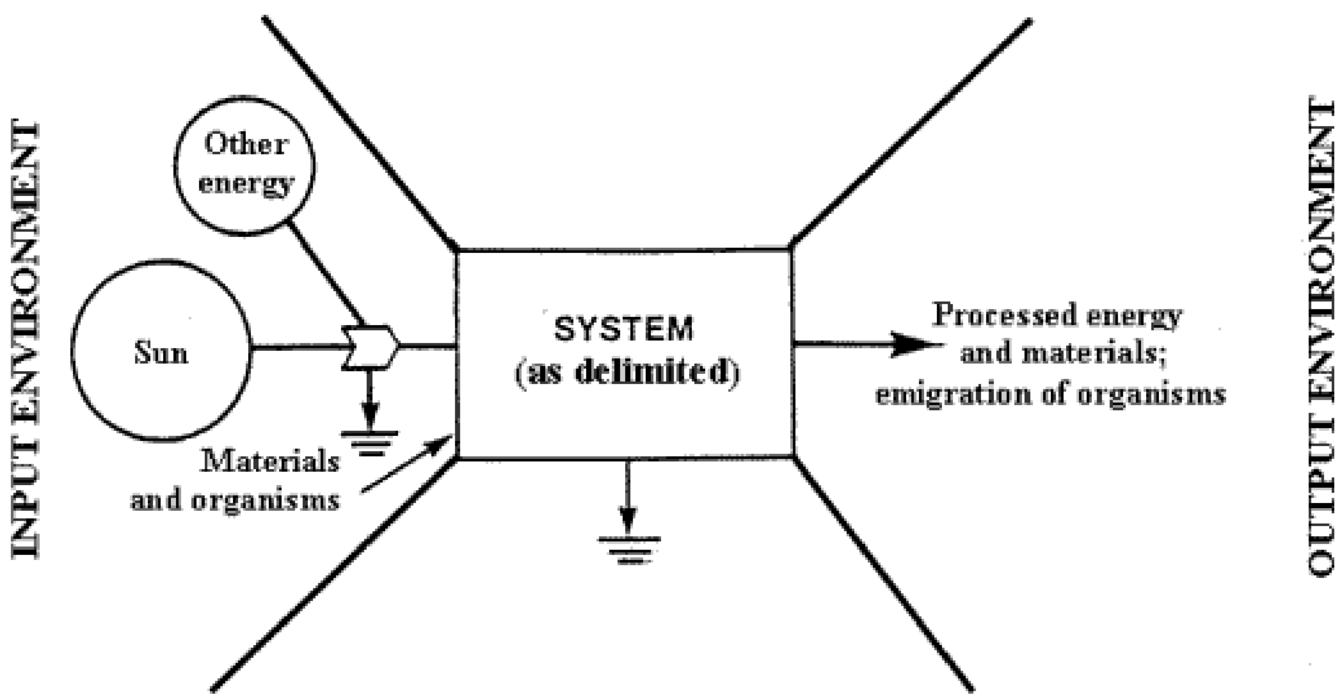
A CONCEPTUAL MODEL OF HUMAN ECOSYSTEMS

Tansley (1935:306) characterized ecosystems as being composed of both the organisms present in an

[1]University of Florida; [2]University of Georgia; [3]Arizona State University; [4]Florida International University

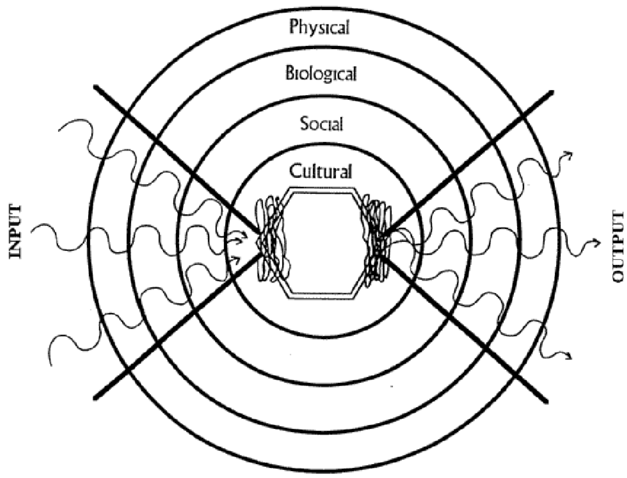
ecological unit and the "... effective inorganic factors of its environment." The ecosystem is one of ecology's most important and fundamental concepts (Cherrett 1988). One strength of the ecosystem concept is that it is appropriate for any situation in which the biological and physical interact, leading to the broad utility of the concept (Pickett and Cadenasso 2002). Although this is useful for the conceptualization of ecosystems in general, the limitation of the definition of ecosystems to the interaction of organisms and their physical environment is insufficient for a full understanding of the nature of human ecosystems. Human ecosystems are driven largely by the interaction of biotic and abiotic components through the flow of information. Full consideration of the flow of matter, energy, and information is necessary to gain an understanding of human ecosystems.

Fig. 1. Environment and ecosystem (Odum 1997, concept based on Patten 1978). There are two environments, an input environment and an output environment, defined by the focal consumer or system. Together they define the ecosystem: IE + S + OE = ECOSYSTEM.



Our view of ecosystems draws from Patten's (1978) definition, as it expands upon the Tansley (1935) conception to include both input and output environments (Fig. 1). In this model, Input Environment + System + Output Environment = Ecosystem. Inclusion of an output environment in this definition allows systems to modify their input environments through their outputs. Moreover, the inclusion of both an input and an output environment makes it possible to conceptually link systems together. Patten's conceptualization recognizes the significance of indirect causality through complex networks of interactions and flows, and permits the exploration of the role of information in ecosystems. A human system is seen as a locus in a set of environments that have both input and output environments. Additionally, Patten's definition of the ecosystem allows for the conceptualization of whole organisms, not just the physicochemical components, as part of a system's environment. Although this conceptualization is important for ecology in general, it is particularly important for this discussion of human ecosystems. An ecosystem definition that is sympathetic to the role of organisms, especially humans, in the input and output environments affords a better understanding of the true nature of human ecosystems by giving full recognition to the processes that drive these systems. The conceptualization of the ecosystem is not constrained by linking only organisms and physical processes.

Fig. 2. A partial concept of multiple environments (after Stepp 1999, cf. Salthe 1985:167). Concentric spheres denote an evolutionary arrangement of the different environments, with an aggregated consumer symbol at the center. Information inputs and outputs to and from the system pass through epistemological filters/fields/editors/screens.



To further define human ecosystems, we add the "multiple environments" concept to Patten's ecosystem (Fig. 2, Stepp 1999). The multiple environments are arranged in an evolutionary hierarchy, with the physical environment preceding and encompassing the biological, and so on. This conceptualization follows the logic of set theory, where each successive environment after the physical environment produces a new set of constraints on the system under consideration (Salthe 1985). An aggregated consumer symbol representing a human population or individual as a transformer of matter/energy/information lies in the middle (after Odum 1983). The wavy lines represent information flows from the multiple environments that pass through an epistemological filter/field/editor/screen for any given individual or population. This represents the co-occurring and often overlapping processes of human cognition, which are shaped by environmental affordances, belief systems, and the types of information that are available. Matter and energy flows are not represented in this depiction but are, of course, present in all human ecosystems. In Fig. 3, we apply the multiple environments and human ecosystem model to a scaled hierarchy in which various ecological disciplines might locate the appropriate environment(s) and scale of its subject matter (Pavao-Zuckerman 2000:35).

PATTEN'S REMARKABLE PROPERTIES OF ECOSYSTEMS

Patten (1978) framed the ecosystem concept around unique input and output environments that relate to each system. The usefulness of the ecosystem concept has been noted by many authors in various fields, but it is Patten's (1998) discussion of 20 remarkable properties of ecosystems that encouraged us to think at greater length about human ecosystems. These 20 properties include the complexity and volume of the indirect pathways that connect hierarchically organized and mutually determining agents, each of which is a unique locus created by several interacting environments. This contribution, i.e., understanding individuals or populations as unique loci in a given environment, methodologically and theoretically helps to bridge the gap between ecosystems and populations. Patten also notes that ecosystems are cybernetic, adaptive model-making systems of inheritance or co-evolution that create new niches while they construe benefits for and equalize energy-matter flows between constituent agents. These properties help maintain a sophisticated understanding of the organization of plants, animals, and matter in any given system. They allow us to talk about several populations and their population dynamics at once, not just theoretically, but also taking into account what we see as scientists. As such, we think that Patten's exercise with ecosystems is correctly applied to human ecosystems.

HUMAN ECOSYTEMS AS INFORMATION SYSTEMS

Along with matter and energy, information is one of the three major components of an ecosystem. This ecosystem framework can be traced back to the systems ecologist Margalef (1958, 1968), although his concept of information was based on the limited definition used in information theory at that time. Information was subsequently neglected for the most part by biological ecologists. Beginning in the 1970s, a series of statements of a largely programmatic nature was written by ecological anthropologists about the need to include the role of information when studying human ecosystems (e.g., Flannery 1972, Adams 1973, Alland 1975, Dow 1975, Bennett 1976, Moran 1982, Butzer 1990).

With regard to humans, Flannery (1972:400) states that "... [t]here is a reason why past 'ecological approaches' have failed, and it lies not in ecology but in the self-styled 'cultural ecologists.' Modern ecologists, who not only analyze but even simulate dynamic ecosystems, [now] take into consideration that all populations exchange matter, energy and information with their environments ... In an ecosystem approach to the analysis of human societies, everything which transmits information is within the province of ecology ..."

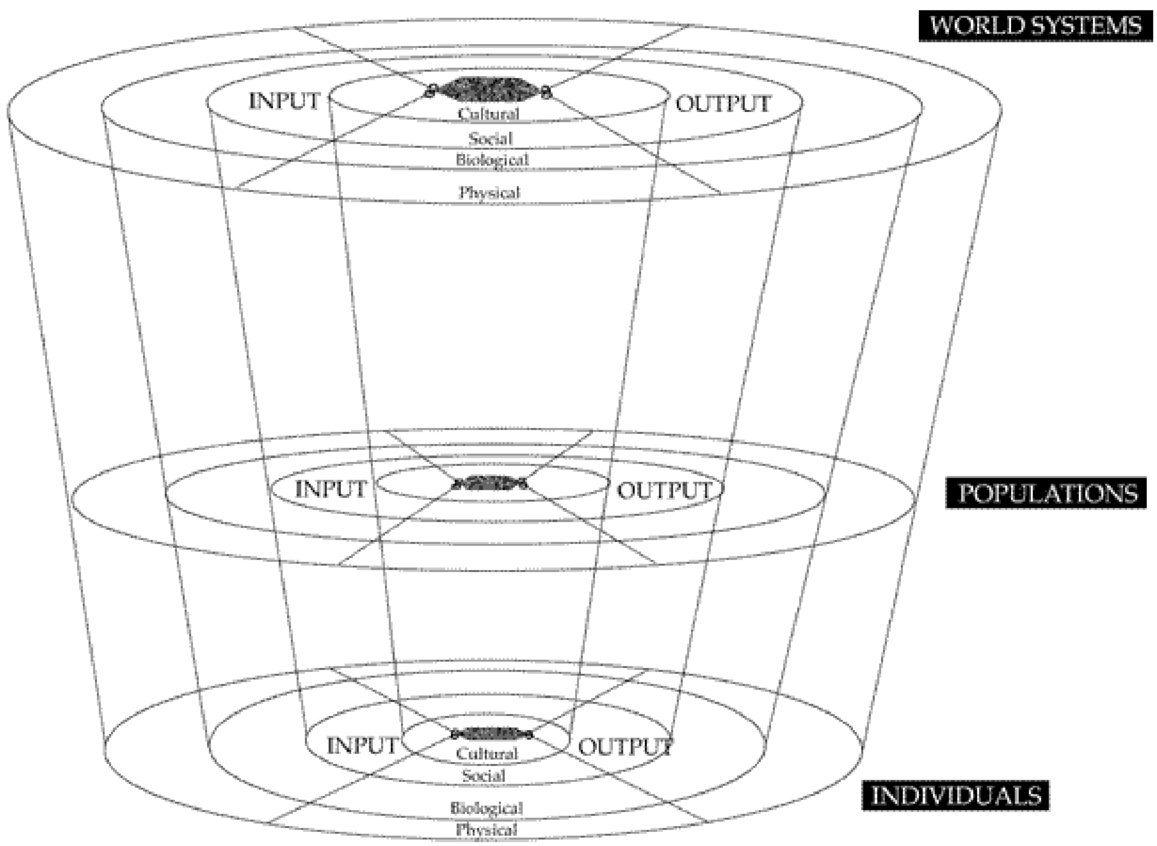


Fig. 3. Partial concept of multiple environments applied to a scaled hierarchy of human ecosystems (Pavao-Zuckerman 2000:35).

During this period, there was a widely held, at least implicit, assumption that ecosystems have flows of matter, energy, and information. However, Flannery's statement that biological ecologists were already studying information was not entirely true; at that time, mainstream biological ecologists for the most part did not study information in a broad context. Odum's (1953, 1959, 1971) classic textbook, *Fundamentals of Ecology*, trained several generations of ecologists. Although it contains many excellent chapters on matter and energy, there is almost nothing on information. The term does not even appear in the index. A survey of some of the leading ecology textbooks in use today shows that the situation has not changed much. Information is rarely mentioned, if at all. When it is mentioned, it is usually in reference to indices from information theory that were subsumed into measures of biological diversity (Ulanowicz 2001) such as the Shannon Index (Shannon and Weaver 1949).

Despite the situation at the pedagogical level, biological ecologists today are exploring ways to incorporate human agency into their theories and research. Readers of this journal are familiar with the efforts of the Resilience Alliance in this area. Other well-known examples of in-depth longitudinal research that integrates human institutions are the Long Term Ecological Research (LTER) sites across the United States (Grimm et al. 2000). Sociocultural components of the ecosystems under study feature prominently in many of these studies. Efforts at integration by other interdisciplinary research consortia are detailed in other papers included in this special issue of *Conservation Ecology*.

Anthropologists can contribute to this exciting development because of their long-standing preoccupation with the informational aspects of human societies such as language and other symbolic behavior. One of anthropology's greatest contributions to ecology may be in the realm of systematically including information into a triad of ecosystem components in both the input and output environments of specific systems. Developing an information ecology, i.e., a subfield of a human ecology that integrates matter, energy, and information, is critical for understanding the remarkable properties of human ecosystems at various levels of social organization, because these properties are fundamentally informational in nature (Stepp 1999). It was through a collaborative endeavor toward this goal that the following properties were conceptualized.

SOME REMARKABLE PROPERTIES OF HUMAN ECOSYSTEMS

The remarkable properties presented here are based on cross-cultural and historical observations of human systems. This does not necessarily imply that these are general principles or human universals, but rather that they are properties that are discernible and often appear in human systems and that they are worthy of further investigation. Rather than provide an exhaustive list, the following set of brief notes is intended to stimulate thought and discussion as we begin to explore the complex dynamics of human ecosystems.

We have organized the presentation of these properties into three categories: (1) information and belief systems, (2) historical vectors of information in human ecosystems, and (3) new kinds of material, energy, and information flows and sinks not found in nonhuman ecosystems (Table 1). Future refinement of the relationship between these and other properties will undoubtedly build on and improve the present framework.

Information and belief systems

We take it as a point of departure that the predominance of information in human ecosystems leads to emergent properties. One example is the appearance of organized systems of meaning that are often paradoxical in structure and ontologically complex because they are located at multiple scales and not just in the individual (e.g., Puleston 1979, Gumperz and Levinson 1991). In this way, belief systems are capable of shaping both human behavior and the course of history (cf. Cronon 1983). Also, the dualistic black/white dichotomy and the absolutes typically provided by religious world views and/or other value systems influence both what people say and what they do. However, despite the uniqueness of human belief systems, the point is not to assign a priori a more privileged role to information in human ecosystems than those played by matter or energy; all of these factors are crucial.

Belief systems

Belief systems bridge various scales of human social organization. At the broadest scale, the noösphere concept recognizes the influence of the human mind on all of earth's systems, at different points in time, in an ever-broadening expanding consciousness (Teilhard de Chardin 1966, Birx 1972). We define human belief systems as those collective and shared epistemologies and ideas that influence and mediate human behavior. Furthermore, they are based on the human species' need to impose conceptual order on a vast range of environmental information while also striving for supernatural experiences. Symbolic belief systems may have a high degree of internal coherence and logic to them. They are, at times, effectively isolated from the "realities" of the biophysical environment. This isolation is created through a dynamic epistemological matrix composed of processes that serve to filter, screen, and restructure informational inputs from, and to, the biophysical environment. The dynamic nature of this epistemological matrix can, on occasion, allow human systems to recognize feedback from the biophysical environment, which potentially leads to changes in the belief system. This functional aspect of belief systems has been explored by anthropologists working in the cultural materialist and the cultural ecology traditions (Harris 1979, Rappaport 1984). In our view, functional aspects of belief systems may be the exception, not the rule (see *Canalization* below). If functional adaptations were the norm, we would see strong correlations between changes in the biophysical environment and subsequent changes in belief systems. However, the persistence, not change, of belief systems across time and space is much more likely, even in the face of dramatic changes in the biophysical environment. This oftentimes "closed" nature of belief systems may derive from limitations in the ability of humans to perceive "... [t]he cybernetic nature of self and world ..." (Bateson 1972:16).

Table 1. Remarkable properties of human ecosystems.

Human ecosystem domain	Remarkable property
Information and belief systems	Belief systems Externalized cognition
Historical vectors of information in human ecosystems	Superimposition of technostructure onto biostructure Historical determinism Canalization Power and institutions of agency
New kinds of material, energy, and information flows and sinks	Burial, destruction and discarding of wealth Highly destructive intraspecific aggression Fetishization of material flows

Externalized cognition

The human central nervous system has a well-developed capacity for externalized cognition, or the exteriorization of knowledge, awareness, and judgment, which is manifested in communicative signs, behavior, or material artifacts. Human cognition is a process by which objects and actions take on meanings that do not exist solely in the central nervous system or solely in the objects or actions themselves (Gumperz and Levinson 1991, Hutchins 1995). It is the interactions of internal and external processes that characterize human cognitive abilities, creating the potential for belief systems, institutions, and behavior patterns that shape the relationships between sociocultural and biophysical environments.

Arising from this capacity, human ecosystems are often characterized by complex, human-generated representations of the system itself, which can be used to generate or reformulate goals for all or parts of the system (Bateson 1972:102). The goals are often reified and then imagined to have a foreseeable effect on the future. Many indirect effects arise from this, and it represents an important area for further investigation. For example, because goal formulation or planning in human ecosystems is affected by belief systems, human interactions associated with belief systems can interrupt feedback, whether positive or negative, from the sociocultural and biophysical environments. Thus, the planning process can be directed toward goals that seemingly benefit only a small segment of society, while thwarting the ability of other segments of society to represent and externalize the system sufficiently and accurately. As a result, human ecosystems are informationally driven by a complicated mixture of fact, fiction, and fantasy.

Historical vectors of information in human ecosystems

Information in human ecosystems contributes to complexity, technological change, and forms of historical determinism. All ecological systems possess degrees of complexity. However, care must be taken to distinguish between processes that alter the complexity of a system and those that complicate a system (Hallpike 1988, Allen et al. 1999, Allen et al. 2001). The elaboration of the organization of a system increases its complexity. This change in complexity involves an increase in the vertical differentiation in a system, adding to the levels in the system's hierarchy of organization, e.g., agencies within government ministries. Complication is an elaboration of a system's existing structure, e.g., elaborate and overlapping sets of social relationships that are formalized in kinship systems.

Thus, although complexity adds levels to the hierarchical organization of a system, complication adds to the structure within a level of a hierarchy. System behavior will tend to become simpler as the number of levels increases because of a stronger and more direct pathway of flow within the system. Thus, human ecosystems characterized by increased complexity may be simpler to understand than human ecosystems that are either complicated or lacking complexity. In part, this may be to due to the clearly defined markers that are found in complex social organizations to denote status within a hierarchy. However, the implications of this potentially improved understanding are less clear for the management of human ecosystems because of the continued existence of slow-changing belief systems.

Superimposition of technostructure onto biostructure

There is an increasing imposition on biostructure by technostructure in human ecosystems over time that we call "technosubstitution," which leads to an increase in thermodynamic flows and sinks (Kuchka 2001). This technical and technological advance of human society occurs despite the conservative tendencies of many belief systems. One of the most salient examples in human cultural evolution is the intensification of production via technologies. Examples from human cultural evolution can be seen in the major technological transformations associated with agricultural intensification, such as plows that give access to deeper soils, steam power to run threshing machines, or fossil fuels to produce fertilizers and pesticides. During each sociotechnical stage of human ecosystem development, technological structure has supplanted the biostructure that, up until then, had been responsible for supplying the plants and animals for human subsistence. Although these advances lead to greater output, they do not lead to greater efficiency but rather to increased inefficiency from a thermodynamic standpoint (Pimentel et al. 1973). The process of technosubstitution via resource intensification is not driven simply by feedbacks from population growth or pressure (cf. Boserup 1965). It is a process that is directly related to the semiotic abilities of our species.

Historical determinism

History strongly, and sometimes dialectically, determines the trajectory of human ecosystems. A few examples of historical determinism include (1) recognition of how the persistence and spread of institutions in cultural evolution relates to social structure and ideology, both of which reduce the randomness and increase the directionality of cultural evolutionary change (Hallpike 1988:208); (2) population growth that causes specialization and stratification of social relations (Hallpike 1988:237-252); (3) negotiations, transfers, and compromises that are largely dependent on prior information; and (4) an increasingly human-built output environment that dominates the informational input environment.

A corollary of historical determinism is that, as political complexity increases in human ecosystems, information flows favor short-term gain over long-term homeostasis. Short-term gains in the context of ecosystem theory connote a low level of system maturity and high rates of energy flow. In state-level societies, attention is focused on a relatively short period of time in which environmental manipulation is undertaken at the expense of long-term considerations. The important question here is: when, how, and under what conditions are long-term considerations for human ecosystems expressed? Although some small-scale societies may manage their biophysical environment in a sustainable manner (Anderson 1996), it is unclear as to the exact conditions necessary and sufficient for such interactions. The ongoing polarized debate in anthropology and the social sciences as to whether or not small-scale societies are ecologically sustainable (cf. Redford 1991) has not adequately addressed the underlying causes one way or the other. Smith and Wishnie (2000) suggest that conservation of this type must be overtly purposeful and not accidental to be truly sustainable.

Canalization

As a result of historical determinism, canalizing functions occur that can restrict the potential manifestations of cultural processes once they are widely accepted and adopted. In the early stages of adaptation of any cultural process, a wider variety of selective pressures plays a role than in later stages, although this is not necessarily an orthogonal function. Also, as Hallpike (1988) demonstrates with the concept of "survival of the mediocre," the persistence of a cultural trait, both in behaviors and institutions, may have little to do with its continued adaptive value or efficiency. Rather, it is because a given cultural practice or structure can muddle through a variety of circumstances and affords relatively easy social reproduction (Boyd and Richerson 1985) that it continues to persist in human cultural evolution.

For example, Harris' (1966) cultural materialist/functionalist explanation of the sacred cow complex in India is compelling with regard to its origin. The basic argument is that cattle in India were more valuable alive to serve as plow and milk animals and to provide dung for fertilizer and fuel. This led to the development of a taboo against consuming beef among Hindus. However, this argument does not account for the persistence of the taboo when keeping a large number of cows around ceases to be advantageous, such as when Indians migrate to Western industrialized countries.

Other cultural features embedded in belief systems may undergo similar trajectories. With the loss of their adaptive value they may become neutral or even maladaptive/unsustainable, but nevertheless exhibit long-term persistence. Arthur's (1990) concept of "lock-in," in which a small advantage at the onset leads to a cultural feature becoming locked in as the system develops (cf. "generative entrenchment" in Wimsatt 1986) becomes relevant here. Two other relevant concepts are Puleston's (1979) concept of epistemological pathologies and Rappaport's (1977, 1984) concept of hypercoherence. Puleston attempted to explain the role of information and belief in the collapse of Classic Maya civilization. Although he did not ignore the considerable evidence of environmental degradation, he argued that the belief among the Maya that the world undergoes upheaval every 256 years led people to simply give up when faced with mounting pressures from overexploitation of their biophysical environment. Rappaport argued that increased informational pathways and interactions lead to instability because localized pathologies can extend throughout the entire system.

Power and institutions of agency

For humans, power has its sources in the capacity for imagination without discernible bounds, which results in human refusal to admit limits to power (Russell 1938). However, the exercise of power requires a motivation. Motives for the exercise of power are ubiquitous, and such motives may be exaggerated by human attempts to transcend the natural world through supernatural experiences. Power becomes increasingly important in the maintenance of human ecosystems as they become more complex. With the advent of the city and nation-state, the biophysical environment grows less and less important compared with the interpolity interactions that come to dominate the input and output environments. These interpolity interactions owe much of their nature to the goals of military institutions. Militaries prove particularly noteworthy for their contributions to technological change in societies, especially in the context of the state (Jones 1999).

New kinds of material, energy, and information flows and sinks

The remarkable success of culture in mediating human interactions with biological and physical environments leads to surplus material conditions. Consequently, individuals and groups can devote time to creative, imaginative, and supernatural experiences. These pursuits are often linked to material, informational, or energetic flows and sinks. Given such complex cognitive capabilities, it is perhaps inevitable that some informational processes emerge that are dysfunctional and perverse. Most of the remarkable properties discussed above can, in some cases, contribute to dysfunctional processes. The impact of the current global system on various ecological processes compels us to consider the relationship between these remarkable properties of human ecosystems and the biophysical world. Nonetheless, we caution against blanket statements about adaptability, sustainability, or functionality, because we still do not have a fully formed theoretical framework that allows for the long-term investigation of human ecosystems. Below are several specific examples of unsustainable and seemingly dysfunctional practices that have occurred in various human ecosystems over time.

Burial, destruction and discarding of wealth

Some cultural traits may arise that apparently lack adaptive value, although the authors recognize that the level and scale of analysis certainly circumscribe what might be considered adaptive or even sustainable. Rather than characterize these traits as adaptive or not, we suggest that they all have in common a tendency to systematically remove matter, energy, and information from their typical flows. This may be due to the emergent property of surplus capacity for production in human systems. As an example, we note that funeral customs in many places in the world remove large amounts of wealth from circulation and material use through the burial of valuables, tools, and money (Kuchka 2001). We see this occurring in Iron Age Denmark with the Vikings, who in victory made offerings to lake deities in the form of war booty and enemy ships, which they dragged from the sea's edge and scuttled inland (Klesius 2000). In Ancient Egypt and Classic Maya civilizations, we also find burials of enormous amounts of wealth to serve the dead in the afterlife. Other forms of destruction of wealth include warfare and military testing, as well as planned obsolescence of consumer goods.

Highly destructive intraspecific aggression

Intraspecific aggression is not unique to humans. Neither is group cooperation in the commission of intraspecific aggressive acts (O'Connell 1988). However, such cooperation along with ideologies of unrestrained power and supernatural beliefs often results in catastrophic loss and destruction of human populations and severe alteration and destruction of their biophysical environments. A notable example is the testing and use of thermonuclear weapons of mass destruction.

The degree to which human societies engage in violence among themselves has troubled scholars and philosophers at least since the origin of writing systems. One interpretation we offer is that human systems do not exist in isolation, based on Wilkinson's (1995) principle that any given civilization cannot be considered apart from others. He defines civilization as the systematic interaction of more than one human society, whether through trade, warfare, or subjugation. In addition, Jordan (1998) argues that every human group requires the existence of other groups to legitimize its identity. Thus, it is possible that intraspecific human aggression might actually serve the function of maintaining group identity while still acting as a sink for human life and property.

Fetishism of material flows such as commodities and money

Marx (1967) noted that social relationships between people become hidden or obscured through the process of economic exchange. These relationships are increasingly experienced as relations between material items that begin to take on symbolic value. Money in human societies plays a unique role as the universal sign/token of equivalent value. When it becomes a fetish, it affects information flows in a manner far beyond its base material equivalent. This behavior depends on the previously discussed remarkable properties of externalized cognition, the desire for supernatural experience, and the potential power that access to fetishes might afford. An excellent historical example is the commercial fetishism of tulips in Holland during the 16th century (Mackay 1980). A more recent example is found in the rise and fall of "dot.com" companies in the stock market.

CONCLUSIONS

Human ecosystems are remarkable in terms of their informational qualities. Belief systems tend to exclude feedback from multiple environments, making human ecosystems difficult to change. The remarkable properties that nurture this tendency are not presented to serve as interesting snippets of the human experience but rather as heuristic devices that may stimulate creative exploration toward a more integrated ecology. The impact of remarkable properties on sustainability is still largely unknown because a framework does not exist in which to consider the long-term viability of human ecosystems. Nonetheless, our discussion points to some tendencies of human behavior that contribute to a seeming inability to recognize or adequately respond to the ecological context that we live in.

Responses to this article can be read online at: http://www.consecol.org/vol7/iss3/art11/responses/index.html

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