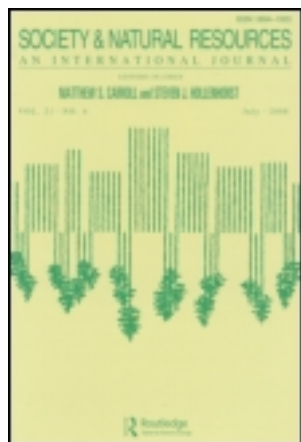


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The human ecosystem Part I: The human ecosystem as an organizing concept in ecosystem management

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The Human Ecosystem

Part I: The Human Ecosystem as an Organizing Concept in Ecosystem Management

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The organization and description of a comprehensive ecosystem model useful to ecosystem management is necessary. In this article, we propose the human ecosystem as an organizing concept for ecosystem management. First, we describe the history of the human ecosystem idea; both biological ecology and mainstream social theories provide useful guidance. Next, we present the key elements of a human ecosystem model: critical resources (natural, socioeconomic, and cultural), social institutions, social cycles, and social order (identities, norms, and hierarchies). In each element, we (1) provide a general definition and description, (2) suggest ways that the variable can be measured, and (3) give selected examples of how it may influence other components of the human ecosystem. The article concludes with specific suggestions as to how the human ecosystem model can play an organizing role in ecosystem management.

Keywords ecosystem management, human ecology, human ecosystems, social theory

[T]he ultimate challenge for Ecology is to integrate and synthesize the ecological information available from all levels of inquiry into an understanding that is meaningful and useful to managers and decision makers. G. E. Likens (1992, 3)

In the early decades of the twenty-first century, a major challenge likely will confront the natural resource professions. Depending on one's source, somewhere around 2020, the

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globe will contain 6 to 8 billion humans (Demeny 1990; World Resources Institute 1994). There is little evidence that this human population, with its ever-increasing expectations, will experience a voluntary redistribution of resources from the well-to-do regions, classes, and persons to the poorer regions, classes, and persons. Our past hopes have been based on technologically induced supply increases from a finite resource base that would permit some trickle-down effects. In the United States, trends suggest more polarization between rich and poor, and increased struggle over resources.

Consequently, the natural resource professions will need to intensify their search for models of resource systems that include the forces driving infinite human desires, along with the more limited possibilities of satisfying those desires with increased natural resource productivity. Human variables as both the cause and consequence of system change will need to be joined to the traditional biophysical concerns of the forester, agriculturalist, range manager, and park superintendent.

Since 1990, "ecosystem management" has carried the most hopes for finding some coherent and comprehensive means for systematically fitting human demand within biophysical and sociopolitical realities.¹ The organization and description of a comprehensive ecosystem management model is only recently under way; the inclusion of *Homo sapiens* is unrealized. Biologists have focused on "impact" measures of humans, a strategy that puts our species outside the ecosystem as, at most, a permanent perturbation. Social scientists have focused largely on idiosyncratic "human dimensions" outside of and immune to biological reality. The traditional academic divisions have played at intellectual balkanization, seeking advances in territory rather than a more inclusive paradigm that would be truly helpful to resource management professionals. Such a paradigm would be a new kind of life science, one that treats the biosocial reality of human beings as a serious part of its approach toward ecosystem management.

In this article, we describe one version of what a human ecological perspective might offer ecosystem managers. We propose the *human ecosystem* as an organizing concept for ecosystem management. Because our goal is to describe the human ecosystem as a useful structure, we emphasize description of component parts (as a trophic level model might do) rather than critical processes (as a model of succession might do). First, we outline the genealogy of the human ecosystem idea; we draw on a long tradition of intellectual risk taking by many biologists and social scientists. Next, we present the critical elements of a human ecosystem model, followed by a detailed description of the individual variables and their relevance to ecosystem management. We conclude with specific suggestions as to how the human ecosystem model can play a useful role in managing the natural resources of the twenty-first century.

We make no pretense of resolving the larger issues surrounding environment/human studies. Our belief is that the most sustainable joining of biology and social science will come only when both approach the task as equals, with mutual respect for the theory and methods of the other. Our effort is a statement of ecology from a human perspective, with due consideration for biologically centered ecosystem models and social science derived constructs. Our hope is a fusion that transcends the arcane division of the biophysical and the sociocultural—one that is truly ecological.

Background

Studies of the patterns and processes in ecosystems emphasize the diversity and complexity of the elements affecting the systems. This was the central theme of R. L. Lindeman's breakthrough lake studies (1942) and the pioneering Hubbard Brook ecosystem research

(Bormann and Likens 1979; Likens et al. 1977). Their emphasis was on the dynamics of ecosystems in terms of flows, exchanges, and cycles of factors such as materials, nutrients, and energy. From the Hubbard Brook data, Likens et al. noted that

a vast number of variables, including biologic structure and diversity, geologic heterogeneity, climate, and season, control the flux of both water and chemicals through ecosystems. (Likens et al. 1977, 2)

More recently, F. B. Golley also emphasized ecosystem complexity:

the ecosystem consists of co-evolved suites of organisms . . . there are keystone species that provide special environments for many other groups. There are also social organisms, such as ants, that form yet another pattern of organization. This means that the actual organization of an ecosystem is much more complex than the network model suggests. Indeed, the organization of a large city might be a better model than the systems models of textbooks, the links of which if very complicated look like a bowl of spaghetti. (Golley 1993, 203)

It is partly this complexity that has caused biologists generally to exclude human behavior from their models, and social scientists to remain largely at the level of metaphor.²

As the social sciences emerged as self-conscious disciplines in the nineteenth century, they struggled with the problem of how much human behavior should be attributed to our biological nature and how much to our social nature. Obviously, humanity shares characteristics with the animal kingdom, particularly the large nonhuman primates. At the same time, there is a sense of great difference. Causal priority seems to shift from one polarity to another. For some, human behavior is determined by genes, or anatomy, or chemistry. For others, human behavior is determined by norms, or moral values, or the mind, linguistic constructs, demography, or God's grand design. Human ecology is particularly at risk in such discussions, as it attempts to account for environmental variables and biological predispositions, and to merge these with social variables unique to humans such as symbolic language, elaborate normative systems, values, and meanings.

P. A. Sorokin, in criticizing the application of organismic analogies to human society, captured the reality of social science attempts to include the biological domain. He noted that

sociology has to be based on biology; that the principles of biology are to be taken into consideration in an interpretation of social phenomena; that human society is not entirely an artificial creation; and that it represents a kind of a living unity different from a mere sum of the isolated individuals. These principles could scarcely be questioned. They are valid. (Sorokin 1928, 207)

He went on to critique organicist, biosocial, geographic determinist, and demographic approaches to explaining human behavior and the patterns and processes of human society. To Sorokin, all such explanations suffered from too much dependence on analogy and too strong a desire for single causes. Yet, each of the mainstream theories critiqued by Sorokin, and those that have emerged since, have had to find some rationale for attributing, incorporating, excluding, or compartmentalizing the priorities of environment, biology, and human culture. Each theory must assume that the observed regularities in human social life have an explanation.

Mainstream social theories have tended to cluster around certain biophysical and environmental determinants as key. For example, the structure of a society and its processes

of stability and change have long been attributed to “carrying capacity” levels as population presses against resource constraints (Catton 1982; Durkheim 1933; Sumner and Keller 1927). Or, the structures and processes may be attributed to spatial differences in resource “meanings” (Hawley 1950, 1986; Park and Burgess 1921). Or, the ecological processes and environmental conditions may be considered as aspects of symbolic systems (Firey 1960; Wirth 1928). Or, the variety of human organizational patterns and processes may be seen as shaped by environmental variation (Duncan 1964; Selznick 1966). Or, societal patterns and processes are mediated by adaptive technologies, for which the cultural elements exhibit a poor or better ability to accommodate to the technological modifiers (Cottrell 1955; Ogburn 1950). Or, the structure of political power may determine (Marx 1972), and in turn, be shaped (Weber 1968; West 1982) by characteristics of natural resources.

Our point is twofold. The first is that, contrary to contemporary commentary such as Dunlap and Catton (1994), environmental sociology is neither a recent product of sociologists nor distinct from mainstream social theory. The second is to remind the reader that, either explicitly or implicitly, traditional mainstream social theory must make an accommodation to the dilemma of reconciling social and biological facts in understanding our species. An ecology that includes humans is like other zoological studies in that it begins with the biological and environmental conditions of the observed species (Udry 1995), rather than a determined assertion as to how little such factors matter in explaining the observed behavioral patterns. Indeed, our goal is movement toward a unified theory of ecology (Allen and Hoekstra 1992) that ultimately can account for the ecologies of all life-forms. And, a critical starting point is the ecosystem concept.

The Roots of Human Ecology and the Human Ecosystem

The ecosystem was defined formally by Sir Arthur Tansley in 1935,³ and brought into common application by E. P. Odum’s use of the ecosystem as an organizing concept in his 1953 text, *Fundamentals of Ecology*. Several contemporary histories of the ecosystem idea have been published, notably J. Hagen’s *An Entangled Bank: The Origins of Ecosystem Ecology* (1992) and Golley’s *A History of the Ecosystem Concept in Ecology* (1993). Both limit their discussions to the rise of a biological ecology that excludes *Homo sapiens*.

The roots of a human ecology lie primarily in general ecology, sociology, and anthropology, as documented by comprehensive literature reviews (Field and Burch 1988; Micklin 1977) and texts (Hawley 1950, 1986). The application of general ecological principles to human activity was sparked by sociologists at the University of Chicago in the 1920s and 1930s. Sociologists R. E. Park and E. W. Burgess (1921) drew analogies between human and nonhuman communities, describing society’s symbiotic and competitive relationships as an organic web (Faris 1967). Simultaneously, anthropologists such as J. H. Steward (1955), J. W. Bennett (1976), and others began to employ the ecosystem as a tool for organizing fieldwork and research. While the Chicago “school” treated the community (and, for them, that meant the city) as a key unit of analysis, the limited focus on spatial relationships and urban life eventually led to a search for a more holistic framework.

That search (active in the 1950s and 1960s) led to the POET model. This model defined the human ecosystem as the interaction between *population*, *organization*, and *technology* in response to the *environment* (Catton 1982; Duncan 1964). These were to be human ecology’s “master variables”; their interaction the human ecologist’s central con-

cern. A derivative IPAT model (Dietz and Rosa 1994; Erlich and Erlich 1970) modified the interactions to estimate *environmental impacts* as a function of *population*, *affluence*, and *technology*, rather than describe human ecosystems.

In the 1980s and early 1990s, anthropologists such as E. F. Moran (1990), sociologists such as W. R. Burch Jr. and his colleagues and students (Burch and DeLuca 1984), and ecologists such as H. T. Odum (1983) and E. P. Odum (1993) employed the human ecosystem as a theoretical framework. It was applied to archeological research (Butzer 1990), energy policy (Burch and DeLuca 1984), threats to national parks (Machlis and Tichnell 1985), and anthropogenic impacts on biodiversity (Machlis 1992).

The Human Ecosystem Defined and Described

In this article, the *human ecosystem* is defined as a coherent system of biophysical and social factors capable of adaptation and sustainability over time. For example, a rural community can be considered a human ecosystem if it exhibits boundaries, resource flows, social structures, and dynamic continuity. Human ecosystems can be described at several spatial scales, and these scales are hierarchically linked. Hence, a family unit, community, county, region, nation, even the planet, can fruitfully be treated as a human ecosystem.

While the scale of human ecosystems can vary, there are several essential elements. Figure 1 outlines these elements in a basic model of a human ecosystem. A set of *critical resources* is required in order to provide the system with necessary supplies. These resources are of three kinds: (1) natural resources (such as energy, fauna, wood, or water), (2) socioeconomic resources (such as labor or capital), and (3) cultural resources (such as myths and beliefs). These resources keep the human ecosystem functioning; their flow and distribution are critical to sustainability. Some critical resources may be indigenous to the local area (and used locally or exported), others may be imported from adjacent or faraway locales. For example, urban sources of investment capital and national media sources of information are integral parts of rural human ecosystems, as are other distantly produced, but critical, supplies.

The flow and use of these critical resources is regulated by the *social system*, the set of general social structures that guide much of human behavior. The social system is composed of three subsystems. The first subsystem is a set of *social institutions*, defined as collective solutions to universal social challenges or needs. For example, the collective challenge of maintaining human health leads to medical institutions, which can range from traditional shamans to modern hospital systems, rural health cooperatives, and preventive care. Other social institutions deal with universal challenges such as justice (law), faith (religion), and sustenance (agriculture and resource management).

The second subsystem is a series of *social cycles*, which are the temporal patterns for allocating human activity. Time is both a fixed resource as well as a key organizing tool for human behavior. Some cycles may be physiological (such as diurnal patterns); others institutional (permitted hunting seasons). Still others may be specific to the individual (such as graveyard shifts) or environment (such as climate change). Social cycles significantly influence the distribution of critical resources. An example is the set of collective rhythms within a community or culture that organize its calendar, festivals, harvests, fishing seasons, business days, and so forth.

The third subsystem is the *social order*, which is a set of cultural patterns for organizing interaction among people and groups. The social order includes three key mechanisms for ordering behavior: personal identities (such as age or gender), norms (rules for

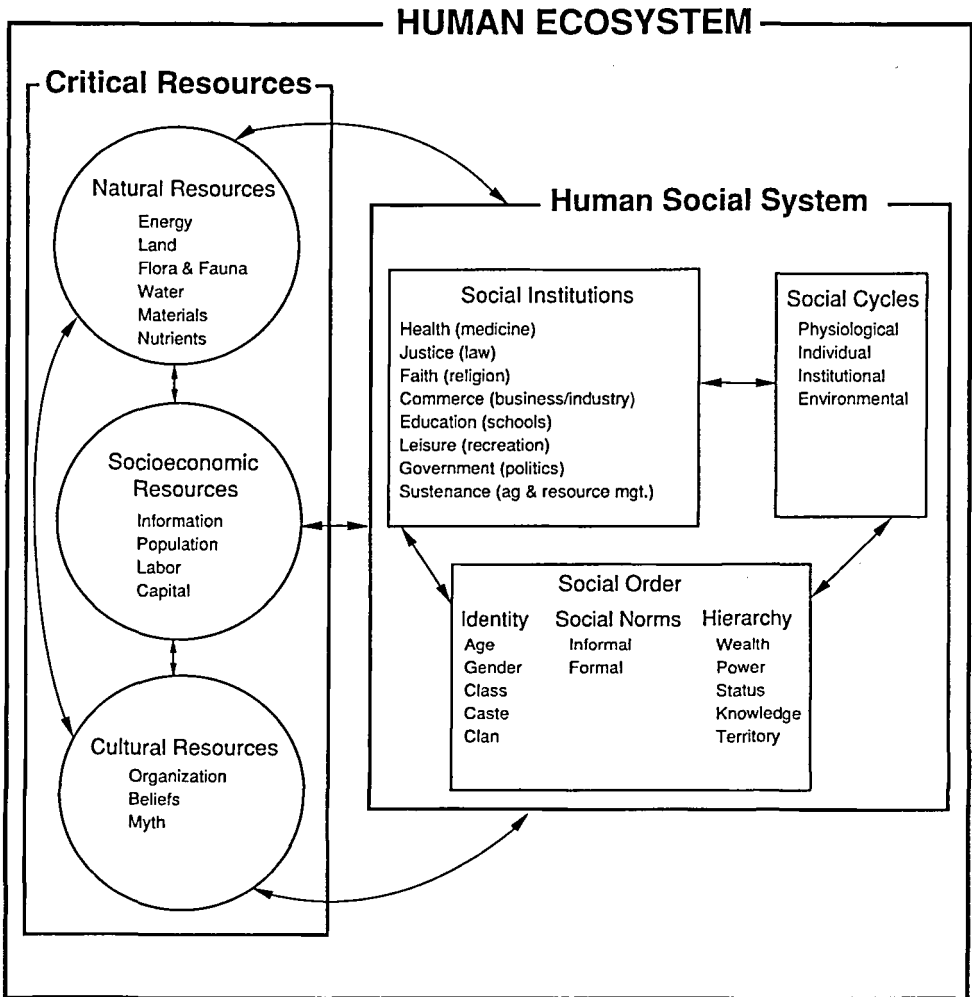


Figure 1. Working model of the human ecosystem.

behaving), and hierarchies (for example, of wealth or power). Hence, certain predictions about interaction are created when one can identify the age, gender, status, and power of individuals or groups, and such expectations allow the social system to function.

The social order (individually, collectively, and in relationship to social institutions and social cycles) provides high predictability in much of human behavior. Taken together, social institutions, social cycles, and the social order constitute the social system. Combined with the flow of critical resources, this creates the human ecosystem. Each of these elements substantially influences the others. For example, changes in the flow of energy (such as an embargo and resultant rationing) may alter hierarchies of power (those with fuel get more) and norms for behavior (such as informal sanctions against wasting fuel).

Adaptation is continuous in human ecosystems (Bennett 1976); social institutions adapt to changes in resource flows, and in turn, alter such flows. The result is a perpetually dynamic system. For example, political institutions may adapt to the increased de-

mands on forest resources by altering decision-making processes (such as increased public participation) and the resource flow (as when the legal system issues injunctions against timber cutting). Adaptation is used here in a nonvalued sense; what is adaptive (or advantageous) for one institution or social group may be maladaptive (or harmful) for another (Bennett 1976, 1993).

Finally, a particular human ecosystem may be hierarchically nested within human ecosystems at different scales. Hence, the rural community as a human ecosystem may be linked to a larger watershed, region, and state, and to smaller human ecosystems such as clans or households. Changes in a human ecosystem at one scale may have effects at larger and smaller scales. For example, a rise in rural unemployment may impact family health conditions, increase demands on community doctors, and deplete state medical funds.

This human ecosystem model provides an organizing framework for ecosystem management. Each of its key components is discussed below.

Key Components in the Human Ecosystem

In this section, we identify and describe the key components in human ecosystems as shown in Figure 1. For each component or variable, we (1) provide a general definition and description, (2) suggest ways the variable can be measured, and (3) give selected examples of how it may influence other components of the human ecosystem.

Natural Resources

Energy. Energy is the ability to do work or create heat. Energy is a critical natural resource and its influence on social systems is well documented (see, for example, Rosa et al. 1988). As Cottrell (1955) noted, the energy available to humans "limits what we can do, and influences what we will do." Energy flows vary by type of source (hydroelectricity, petroleum, natural gas, solar, nuclear, wood, and so forth) as well as quality (high or low entropy) and flow (continuous, cyclical, or interruptible). An important element is the locus and scale of control (external or internal, local or global, multinational or household). Energy can be measured by heat output (kcal) or economic value (\$/kcal). Changes in energy flows can dramatically alter social cycles and the social order (witness the North American oil shortages in 1973 and 1979), and can force social institutions (such as the recreation industry or agriculture) to make significant adaptations.

Land. Land includes both terrestrial surface, subsoil, and underground features. Land is a critical resource for both its economic and cultural value (Zelinsky 1973). It can be characterized by ownership patterns (public or private), cover (vegetation or plant community types), use (such as agricultural, forestry, urban), and economic value. Changes in land use often can be measured in hectares/land cover–land use type. Such changes often follow restricted and predictable trajectories, as forested land is altered to agricultural and then urban uses (Turner et al. 1990). Land ownership powerfully influences many social institutions (sustenance and commerce are examples), and changes in land use often are reflected in altered hierarchies of wealth, power, and territory through shifts in land tenure and property rights.

Water. Water includes surface, subsurface, and marine supplies. Groundwater (quickly renewed) and aquifers (a form of capital stock not easily renewable) both can be integrated into human ecosystems. Water resources can be characterized by quality, flow (acre-feet/second), distribution patterns, and cyclical trends (such as wet years or drought

periods). The control and distribution of water is a major source of economic, social, and political power (Reisner 1986). Changes in water quality can impact social institutions such as health and commerce; water rights are crucial to maintaining social order, while access to water influences wealth.

Materials. Materials include basic products largely derived from natural resources. Examples include fertilizers (petroleum as a source), dimension lumber (wood), silver and other minerals (ore), plastic (oil), and glass, concrete, cocaine, and denim. The variety of materials used by human ecosystems varies by culture, stage of economic development, and consumption patterns. Common measures include economic value/unit and the flow of raw product (by ton, pound, ounce, or milligram). Much of the sustenance and commerce institutions are based on the production, distribution, and exchange of materials. When flows are altered, norms for use can be impacted (conservation incentives increase with price), and certain materials may be critical for specific institutions such as precious gems for industrial use or coca paste for the illegal drug trade (Morales 1989).

Nutrients. Nutrients include the full range of food sources used by a human population. The range of tolerance for nutrient gain or loss is relatively small in *Homo sapiens* (Clapham 1981), making food a critical resource on a continuous basis. Such resources may vary by culture (religious proscriptions may make certain foodstuffs inedible) as well as climate, and both the caloric value and nutritional supplies (such as amino acids) are critical. Modern human ecosystems include a wide range of imported foods (witness espresso coffee beans from Brazil being brewed in Montana gas stations), and few are self-reliant even for short, seasonal periods. The need for food resources certainly influences sustenance institutions such as agriculture. Food carries mythic connotations (the spiritual value of salmon to several indigenous tribes in the Northwest; the turkey as a celebratory poultry). Hence, changes in nutrient flows can alter human health, social norms, and cultural beliefs.

Flora and fauna. Flora and fauna are critical resources beyond their function as nutrient and material sources; a wide range of flora have ecological, sociocultural, and economic value. Plants are vital sources of pharmacopeia (Wilson 1992), myth (the cedars of Lebanon and the redwoods of California are examples), and status (the American lawn; see Bormann et al. 1993). Fauna, including domesticated livestock, pets, feral animals, and wildlife, have significant economic value through activities as wide-ranging as hunting, bird-watching, pet keeping, and in some cultures the production of aphrodisiacs. Flora and fauna can be valued biologically (such as species richness, number of endemic species, population size, genetic diversity), economically (dollar value per bushel, board foot, pelt, head, horn, or hoof), or culturally (proportion of citizens interested in preserving a species). Changes in flora and fauna, such as the threat of extinction or overpopulation, can lead to changes in nutrient supplies, myth, law, sustenance (particularly, wildlife management and farming practices), and social norms toward the natural world.

Socioeconomic Resources

Information. Information is a necessary supply for any biophysical or social system. Information flow (and its potential for feedback) is central to general systems theory (von Bertalanffy 1968), sociobiology (Wilson 1975, 1978), and human ecology (Burch and DeLuca 1984; Hawley 1950). Information may be coded and transmitted in numerous ways: genes, "body language," oral traditions, electronic (digital data), print (local weeklies, national dailies, news magazines), film, radio, and television. It can be measured by both transmission rates (such as amount of local radio programming) and consumption

patterns (such as newspaper circulation rates). Information flow can significantly alter numerous components of social systems such as educational institutions or hierarchies of knowledge. Its impact on other critical resources is also substantial (for example, the importance of maps in land management).

Population. Population includes both the number of individuals and the number of social groups and cohorts within a social system. Population as a socioeconomic resource includes the consumption impacts of people, as well as their creative actions (accreting knowledge, engaging in sexual behavior, providing labor, and so forth). Human population growth is a dominant factor influencing much of human ecology (Hawley 1986) and social systems (Durkheim 1933), both historically (Turner et al. 1990) and within contemporary nation-states, regions, and cities. Growth can be measured by natural increases (births over deaths/year) as well as migration flows. While population can act as an ecosystem stressor, it also is a supply source for many critical components within human ecosystems such as labor, information (including genetic code), and social institutions (Geertz 1963).

Labor. Labor has many definitions; in the human ecosystem model, it is defined as the individual's capacity for work (economists sometimes label this as labor power; Thompson 1983). Applied to raw materials and machinery, labor can create commodities and is a critical socioeconomic resource. There are many measures: labor time needed to create a unit of economic value (hrs/\$100 value), labor value (measured in real wages), labor output (units of production per worker or hour labor), or surplus labor capacity (unemployment rates) are examples. Labor is critical to human ecosystems both for its energy and information content; that is, both relatively unskilled yet physically demanding labor (such as harvesting crops) and specialized, sedentary skills (such as resource planning or stockbroking) have economic and sociocultural importance. Changes in labor (such as increased unemployment) can impact a variety of social institutions and hierarchies from health care to income distribution.

Capital. Capital can have a range of meanings. A narrow definition treats capital as the "durable physical goods produced in the economic system to be used for the production of other goods and services" (Eckaus 1972). Other definitions include "human capital," financial capital, and so forth (McConnell 1975). In the human ecosystem model, capital is defined as the economic instruments of production; that is, financial resources (money or credit supply), technological tools (machinery), and resource values (such as underground oil). Hence, technology, a critical variable in the POET model, is considered a form of capital available for application in the human ecosystem. These instruments of production provide the basic materials for producing (with labor inputs) commodities. Capital is a critical socioeconomic resource; its influence over production, consumption, transformation of natural resources, and creation of by-products (such as pollution) is significant. Capital often is measured in dollar values, either for commodities produced or the stock of capital on hand. Changes in capital, either in its mix of sources (a new processing plant or mill) or output (a reduction in profits earned by the plant or mill), can alter social institutions as well as hierarchies of wealth, class identities, and other features of the human social system.

Cultural Resources

Organization. In the human ecosystem model, organization is treated as a cultural resource, for it provides the structural flexibility needed to create and sustain human social systems. That is, the special ability of our species to create numerous and complex orga-

nizational forms is a necessary skill in interacting with nature and society (Wilson 1978). It is a cultural resource because there is demonstrated wide variation among cultures in how these generic organizing skills are employed. For example, citizens of the United States are willing to create, continually and often, new organizations to deal with collective issues: building a water supply system (irrigation districts), managing education (school boards), caring for the poor (welfare societies), and so forth. Organization can be measured by its diversity (the range of organizational types), intensity (the number of organizations), or saturation (the percentage of the population that claims membership). Organization is critical to natural resource management; ecosystem management itself is an experiment in new ways of organizing the relations between human and nonhuman domains.

Beliefs. Beliefs are statements about reality that are accepted by an individual as true (Boudon and Bourricaud 1989; Theodorson and Theodorson 1969); citizens may have the belief that forests are being overcut, that water quality is low, or that certain salmon stocks may not be endangered. (Beliefs differ from values, which are opinions about the desirability of a condition.) Beliefs arise from many sources: personal observation, mass media, tradition, ideologies, testimony of others, faith, logic, and science. Beliefs are crucial to human ecosystem functioning, for they supply a set of "social facts" (Durkheim 1938) that individuals, social groups, and organizations use in interacting with the world. Hence, environmental interest groups and industry associations rely on a public set of beliefs concerning environmental crises (which may or may not be factual) to energize and increase their membership. Beliefs can be measured by their ideological content (liberal or conservative), intensity (the proportion of a population that feels strongly about a belief), and public acceptance (the proportion of a population that shares a similar belief). As beliefs change, social institutions often are forced to respond. For example, the changing public beliefs concerning the safety of nuclear power has led to a decline in nuclear power production in the United States (Dunlap et al. 1993).

Myths. To the human ecologist, myths are narrative accounts of the sacred in a society; they legitimate social arrangements (Malinowski 1948) and explain collective experiences (Burch 1971). Hence, myths are an important supply variable because they provide reasons and purposes for human action. Myths are critical to human ecosystems as guides to appropriate and predictable behavior (witness Smokey Bear's admonitions about fire); they give meaning to and rationale for a wide range of social institutions and social ordering mechanisms. For example, the myth of "manifest destiny" provided U.S. citizens at the turn of the century with a rationale for the permanent and private development of the American West; indigenous tribal groups simultaneously called on traditional myths to legitimate their role as temporary stewards of communal land (Worster 1992). Myths operate at various scales: national myths (such as the manifest destiny), community myths (a timber town's story of how and why it was founded), and clan myths (a family's story of its early matriarchs). Myths are difficult, but not impossible, to measure: festivals, symbols, and legends all are indicators of myth supply. A change in myth (such as reduced perception of community self-reliance) can impact social institutions (such as faith) and a variety of social norms as well as resource use (such as wilderness).

Social Institutions

Health (medicine). The health care institution encompasses the full range of organizations and activities that deal with the health needs of a human ecosystem. Health care in modern industrial societies is relatively complex, including primary care (personal and

family health maintenance, outpatient activities by general practitioners), secondary care (such as services of specialists), and tertiary care (such as hospital procedures involving surgery [Rodwin 1984]). Health care institutions often are measured by capacity (the number of doctors or hospitals per 1,000 population) or outcomes (such as infant mortality rates). In rural communities, primary care often is available locally; secondary and tertiary care often are provided on a regional basis. Hence, relatively small changes in the health institution (a doctor's retirement, the closing of a pharmacy) may have direct and indirect effects that ripple through the social system.

Justice (law). The collective problem of justice faces all human social systems; its role in human ecosystems is critical. Two forms are central: distributive justice (who should get what, such as property rights [Rawls 1971]) and corrective justice (how formal norms should be enforced, such as rules for punishment [Runciman 1966]). The legal system can be measured both by its practitioners (such as the number of lawyers or judges/1,000 population) and its performance (number of trials or convictions). The contemporary legal system plays an important role in ecosystem management—the courts influencing distributive justice through timber sale appeals and injunctions, and meting punishment for resource crimes (such as poaching). Changes in legal institutions, such as new procedures for appeal or new laws (the revision of the Endangered Species Act is an example) can dramatically and directly impact the use of natural resources, the development of capital, and other components of the human ecosystem.

Faith (religion). To the human ecologist, religion as an institution has two components: (1) its social function as a system of organizations and rituals that bind people together into social groups (Durkheim 1938) and (2) a coherent system of beliefs and myths (Weber 1930). Both are critical to human ecosystem functioning. Religion, like other social institutions, can be measured by diversity (range of religious practices), capacity (number of churches), or participation (percentage of the population claiming membership). Religion impacts the social system in many ways, altering social cycles (religious holidays), providing identity for both caste and clan, and influencing beliefs and myths. A change in faith (such as increased demands after a natural disaster) can have significant bearing on how effectively social systems will adapt to new ecological and socioeconomic conditions.

Commerce (business and industry). All societies require a system for exchanging goods and services, and the institution of commerce is central to this exchange (Durkheim 1933). Commerce includes not only the exchange medium, but the organizations that manage exchange such as banks, markets, warehouses, and retail outlets. Modern industrialized societies (including their rural regions) rely on a mix of exchange styles; the typical U.S. rural community usually conducts its commerce through a mix of cash, credit, and barter (Machlis and Burch 1983). Commerce can be measured as capacity (such as the percentage of production capacity utilized, or the number of banks) or as a flow (the number of transactions, or the dollar value of a gross regional or local product). Commerce in rural areas, particularly in the West, is largely dependent on local natural resources (be it water, energy, timber, scenic or other values [West 1982]). A change in commerce can create a cascading set of impacts on other social institutions (such as sustenance), the social order (shifts in wealth or power), social cycles (as in a recession), and critical resources (such as land or labor).

Education (schools). Individual *Homo sapiens* are born into the world sorely lacking in the knowledge needed to survive, adapt, and interact with others. Hence, education (the transmission of knowledge) is a ubiquitous collective challenge: We must educate our young. While significant learning takes place in the home and on

the streets, the educational institution functions largely through the school system, including public and private schools, teachers, school boards, and parent organizations (Bidwell and Friedkin 1988). Education can be measured as a density (teacher/student ratios), and input (dollars expended per student), and an output (percentage of high school seniors graduating). Changes in the educational system directly impact other components of the social system (such as the timing of leisure activities, distribution of knowledge, availability of skilled labor). Dramatic changes in the institution (such as school consolidation) can have significant effects on the entire human ecosystem.

Leisure (recreation). Leisure (the culturally influenced ways we use our nonwork time) is an important institution in all but the most harsh human ecosystems (Cheek and Burch 1976). Several studies suggest that industrialized societies have less leisure time per capita than agricultural or pastoral ones (Burch and DeLuca 1984; Schor 1992). In industrialized societies, the recreation institution includes formally managed leisure opportunities (bowling alleys, wilderness areas, moviegoing, hunting, and fishing) as well as less formal pursuits (socializing, sexual behavior or courtship, resting) and specialized activities (holidays, festivals, and so forth). Leisure can be measured as an amount (hours per day per capita), as a level of participation (percentage of adults with hunting permits), or as a range (number of festivals or special events). Changes in leisure can impact human ecosystems in several ways, as through direct impacts on commerce (a boom or bust in the tourist industry) and by changing social norms (a decline in festival attendance or a change in gender participation).

Government (politics). The political subsystem is at once a central component of human ecosystems and a result of numerous other components (such as organization, myths, and legal institutions [Shell 1969]). Politics as an institution is a collective solution to the need for decision making at scales larger than clan or caste. It includes the modes of interaction between political units (such as states and counties), the processes of decision making within political units (such as elections and legislative action), and the participation of citizens in political action (campaigns, party activity, referendum, and so forth). Government can be measured by its resources (tax receipts, authorized expenditures, and employees are examples) or its actions (laws passed, hearings held, and so forth). As governments at several scales control critical natural resources (such as the federal government's forestland), changes in government action or process (revision to the Endangered Species Act) can have a significant influence on human ecosystems.

Sustenance (agriculture and resource management). The provision of sustenance (food, potable water, energy, shelter, and other critical resources) is a central and collective challenge facing all social systems (Hawley 1950). The management of that challenge and the production of necessary supplies require agricultural and resource management institutions of some complexity (Field and Burch 1988). Irrigation districts, farmer's cooperatives, timber companies, tree farm associations, extension offices, federal management agencies, and environmentally oriented interest groups are all components of the sustenance institution. Measures include organizational capacity (number of agents/farm, acres in production), output (measured in dollar values or crop tonnage), and range of sustenance products (number of crops or timber types). As agriculture and resource management are the chief methods for transforming critical resources into necessary social system supplies, their importance to human ecosystem functioning is key. Changes in production, efficiency, or distribution can have effects throughout human ecosystems.

Social Cycles

Physiological cycles. *Homo sapiens* has evolved a series of physiological cycles that deeply influence human behavior. For example, diurnal cycles of night and day create peaks of labor and leisure activity; menstrual cycles control reproduction patterns. The life cycle is roughly similar across cultures: birth, childhood, labor, marriage, child rearing, retirement from labor, and death. Each stage of the life cycle creates expectations and norms for behavior (including the use of resources [see Burch and DeLuca 1984]). Measurement can include the proportion of the population at each stage of the life cycle. These cycles create predictable patterns of activity within the human ecosystem: park-going during daylight hours, increases in energy demands during early morning hours (for showering, cooking, heating, and so forth), rituals at each juncture of life cycle stages (such as weddings and funerals). While physiological cycles rarely may change, they may substantively impact human ecosystem functioning at several scales.

Individual cycles. Beyond physiological cycles, individuals may follow time cycles that are personal and idiosyncratic. Examples are graveyard shifts for certain workers (such as bakers or police), part-time or seasonal work (such as agricultural field labor or lumbering), and personal patterns of recreation activity (weekend hiking or camping). These cycles impact social institutions and the use of natural resources. They can be measured by such indicators as employment patterns (for example, the proportion of part-time to full-time workers). Changes in individual cycles can reflect alterations in labor needs, social institutions, or hierarchies of wealth. For example, displaced mill workers may have to travel farther from home for employment, changing family time budgets.

Institutional cycles. Each of the social institutions described above have (or create) social cycles that control the flow of relevant activities (Burch and DeLuca 1984). The legal institution, for example, creates court seasons and trial days; the leisure and sustenance institutions create hunting and fishing seasons. These institutional cycles are critical to human ecosystem functioning, for they provide guidance and predictability to the ebb and flow of human action. Institutional cycles can be measured in terms of frequency (the number of times that persons or groups participate), duration (such as the length of a hunting season), proportion (the percentage of the population involved), or intensity (the depth of the meaning assigned to the cycle, such as the funeral of a national leader). Changes in institutional cycles may directly impact the use of natural resources (for example, a year-round school calendar diversifying park-going patterns), and importantly, the conduct of commerce (such as fishing seasons, field-burning periods, or fiscal year cycles of funding).

Environmental cycles. Not all cycles are socially constructed: environmental cycles are natural patterns that can significantly influence the human ecosystem (Bormann and Likens 1979; Turner et al. 1990). Environmental cycles include seasons, drought periods, El Niño patterns, biogeochemical cycles, short-term successional stages, and long-term climatological change. Drought cycles in the western United States, for example, impact natural resources such as wildlife and forests, the capital needs for dams, reservoirs, and other storage devices, agricultural institutions, litigation over water rights, and many other components of the human ecosystem. The cycles can be measured by duration (such as length of growing season) or occurrence (the proportion of years in a decade with low precipitation). Changes in environmental cycles, such as the end of a drought or the movement of the seasons, can alter ecosystem and social system responses, often significantly.

Social Order

Identity. One of the key ways that social systems maintain coherence and the ability to function is through the use of identity. In sociological terms, identity is often ascriptive—it is assigned by society based on birth or circumstances rather than through the individual's actions or achievements. Caste or race, for example, is ascriptive: One is born into a racial category which then follows the individual throughout the life course. These identities are used (often through stereotyping or other generalizations) to differentiate people and manage interactions: African Americans claim affinity to one another (by the ascription of race), Chinese make similar claims to each other, both groups identify differences between them, and so forth. Other identities are less ascriptive, such as class: Individuals can alter their class through changes in wealth, education, occupation, and so forth.

Several forms of identity are critical to human ecosystems. *Age* is important, for much of human activity is age-dependent (Eisenstadt 1956): Certain occupations (such as mining) are mainly for the young; certain recreation activities (such as white-water sports) likewise are often specialized by age. *Gender* (the socially constructed masculine and feminine roles) is important, both for its crucial impact on social norms and for its differential effects on social institutions—women and men having different access to capital, health care, wealth, power, and other features of the social systems (Weitz 1977). *Class* is important, though its definition is problematic (Abercrombie et al. 1988). Some social scientists define class in purely economic terms (based on occupation or income); others include sociocultural concerns (such as education or social norms). *Caste* (an anthropological term for race and ethnic groupings) is significant for reasons described above. Finally, *clan* (the extended family or tribal group) is crucial, both as a predictor of interaction (most recreation, for example, takes place with family members) and as a source of support. Clans routinely provide health care, financial assistance, even natural resources (such as food or other supplies) to members in need.

These identities can be measured in terms of diversity (the range of ethnic or age groups in a community) and distribution (the proportion of non-Caucasians within a population, the ratio of working-age individuals to dependents). Changes in identity usually impact social systems through an alteration in social norms; an influx of young people, Jews, women, and blue-collar workers leads to shifts in what is expected as well as what people do; these shifts further alter the human ecosystem.

Social norms. Norms are rules for behavior, what Abercrombie et al. (1988) called the “guidelines for social action.” *Informal norms* are administered through community or social group disapproval: Deviating from the norm is noticed, but sanctions are slight. Speaking too loud in a museum or too soft at a football game are examples (as are norms for behavior in campgrounds, along trails, or on fishing boats). The full range of etiquettes for eating, socializing, courtship, and so forth also are informal norms. *Formal norms* are more serious and institutionalized; they usually are codified in laws that not only prohibit certain actions but proscribe punishments for breaking such norms (Wrong 1994). Misdemeanor and felony laws are examples. Sometimes a community's informal norms may conflict with its formal (legal) norms. The results are “folk crimes,” that is, activities that are against the law but not considered harmful by the population. Some kinds of wildlife poaching or illegal woodcutting are folk crimes (Scialfa 1992).

Norms can be measured by both their adherence (the proportion of a population following a social convention, such as marriage before childbirth) and deviance (the number of felonies per capita). Changes in social norms can impact social institutions (divorce directly impacts health and justice for women) and alter resource use.

Hierarchy. An important mechanism for social differentiation, and for managing the social order, is hierarchy. In almost all social systems, hierarchy is ubiquitous; inequality of access is a consistent fact across communities, regions, nations, and civilizations. Five sociocultural hierarchies seem critical to ecosystem functioning: wealth, power, status, knowledge, and territory.

Wealth is access to material resources, in the form of natural resources, capital (money), and credit. The distribution of wealth is a central feature of social inequality and has human ecosystem impacts; the rich have more life opportunities than the poor. *Power* is the ability to alter the behavior of others, either by coercion or deference (Mann 1984; Wrong 1988). The powerful (often elites with political or economic power) can have access to resources denied the powerless; an example is politicians who make land use decisions and personally profit from these decisions at the expense of other citizens. *Status* is access to honor and prestige (Goode 1978; Lenski 1984); it is the relative position of an individual (or group) on an informal hierarchy of social worth. Cultures may vary as to whom is granted high status (for example, teachers are given high status in China, modest status in the United States). Status is distributed unequally, even within small communities, and high-status individuals (such as ministers) may not necessarily have access to wealth or power.

Knowledge is access to specialized information (technical, scientific, religious, and so forth); not all within a social system have such access. Knowledge provides advantages in terms of access to critical resources and the services of social institutions. Finally, *territory* is access to property rights (such as land tenure and water rights). Hierarchies of territory are created when some have strong land tenure (large tracts with secure ownership) and others weak tenure or are landless. This can vary by region. For example, in the arid U.S. West, water rights (granted by historical priority) may be especially crucial, as it is water that limits development (Reisner 1986).

These critical hierarchies can be measured in several ways. Wealth can be measured by indicators such as the range of incomes or the proportion of the population that is below the poverty line. The distribution of power can be indirectly measured by certain decision-making activities, such as elections. It also can be measured by levels of domination and subordination—the disproportion of Blacks and Latinos in prison or on death row, “glass ceilings” faced by women workers, the persistence of spousal abuse, and the relationship between timber workers and company executives. Status can be measured by public polling techniques that capture public opinion; knowledge can be indicated by educational attainment. Territory can be measured by ownership patterns, the distribution of land by size (that is, the proportion of landholders with large tracts), or the distribution of water rights (by acre-feet). Changes in hierarchies, by altering who has access to critical resources and social institutions, can dramatically alter the human ecosystem.

Potential Applications of the Human Ecosystem Model

This human ecosystem model, we hope, is neither an oversimplification or caricature of the complexity that undergirds the human ecosystems occurring in the world. Parts of the model are orthodox to specific disciplines: There is little new in attributing importance to energy or capital as necessary resources. Other portions of the model are less commonplace to resource managers (though still not original)—myth as a cultural resource, justice as a critical institution, and others. We believe the model is a reasonably coherent whole, and a useful organizing concept for ecosystem management. There are several potential applications.

First, the model could be employed as an organizing framework for social impact assessments (SIAs) associated with ecosystem management plans. Such plans will be more broad and multiscaled than the traditional development projects that have been subject to SIAs, and the model may guide resource managers and their social science partners in capturing a full range of possible impacts. For example, changes in land use (such as a shift from timbering to recreation) may impact a full range of social institutions in ways that ecosystem managers and citizens need to anticipate.

Second, the model could serve as a guide for the development of social indicators for ecosystem management. Social indicators have a long tradition in the social sciences and in social policy decisions; at present, their use in natural resource management is experimental. Yet, there is both precedent and potential in constructing a set of social indicators for human ecosystems. Resource managers already employ biophysical indicators of stream quality, tree growth, soil erosion, and so forth. They use these indicators to guide decision making and to monitor the effects of on-the-ground actions, and when done in a systematic way, define the result as "adaptive management." In an accompanying article in this issue (Force and Machlis 1997), we describe how this human ecosystem model was used to select a set of social indicators for monitoring ecosystem management in the Upper Columbia River Basin. Similar efforts have utility for other critical regions, from South Florida to Chesapeake Bay to the Mississippi Delta to Puget Sound.

Third, and an extension of the application described above, is the use of the human ecosystem model as a basis for monitoring other programs directly tied into the activities of natural resource agencies. By collecting and learning from data related to the model's variables, management alternatives that meet local needs for sustenance and long-term requirements for sustainability may be devised. For example, the emphasized role of social institutions in ecosystem order (from health to business to faith) suggests that the inclusion of local leaders beyond the typical political and special interest representatives may have significant benefits for public planning. Human ecosystems with weak or sound institutions may respond very differently to a manager's plan for altered timber harvests, special management zones, wilderness areas, and other forms of ecosystem manipulations. Predicting such variation is an important ecosystem management skill.

Fourth, the model could serve as an introduction to the human ecological sciences for current and future ecosystem managers. Current resource managers, often trained in the postwar disciplines of wildlife, recreation, or forest management, must struggle to overcome their professional concentrations and "trained incapacities." Future ecosystem managers now in the professional schools are being told that a new paradigm for resource management is being developed. Yet, they are being shown that the traditional faculties and departments are not suitable for mastering and synthesizing the broad range of technical and sociopolitical skills needed to enact this new paradigm. The human ecosystem model could function as a basic teaching tool—its description, analysis, application, and critique providing a bridge between the courses, departments, and faculties involved in ecosystem management education.

Fifth, the human ecosystem concept offers an intellectual crossroads for social scientists working on issues related to ecosystem management. Because it is derived from numerous disciplines and explicitly multiscaled, there is opportunity for economists, anthropologists, geographers, political scientists, sociologists, and others to link their work and findings in order to contribute to the model's overall improvement.

Even further, the human ecosystem as an organizing concept is an invitation to cooperation with biophysical scientists, for many of the model's critical variables function in

ways being discovered and described by landscape ecologists, botanists, hydrologists, and others. Golley noted:

It is not clear to me where ecology ends and the study of the ethics of nature begins, nor is it clear to me where biological ecology ends and human ecology begins. These divisions become less and less useful. Clearly, the ecosystem, for some at least, has provided a basis for moving beyond strictly scientific questions to deeper questions of how humans should live with each other and the environment. In that sense, the ecosystem concept continues to grow and develop as it serves a larger purpose. (Golley 1993, 205)

From our own experience, we suspect such efforts at interdisciplinary, mutual learning to be simultaneously difficult and exhilarating.

Conclusion

The human ecosystem has great potential as an organizing concept for ecosystem management. Our model of the human ecosystem, and our selection of variables and the importance we place on them, are of course, preliminary. The model must be tested, applied, revised; that is, it must go through the same “adaptive management” cycles required of the ecosystem management techniques being applied to the nation’s forests, grasslands, parks, and preserves.

But, more broadly, the human ecosystem is a necessary building block in a true life science—one that attempts to grasp the full complexity of the earth’s dominant species. Such a life science is difficult to distinguish at this time. It is doubtful that it will spring from the determinist arguments currently joined in academe, from genes to gender. It is also doubtful that it will be discovered in the specialized researches of the wildlife ecologist or the zoologist. More likely, it will evolve—in advances and retreats—in response to the great necessity of our species to come to an accommodation with our powers, desires, weaknesses, and limits. For the fate of human ecosystems is our own.

Notes

1. There are numerous definitions of ecosystem management, as well as vigorous debate (see, for example, the August 1994 issue of *The Journal of Forestry*). Moote et al., synthesizing the literature, provided a serviceable, if generalized, working definition.

Ecosystem management is a management philosophy which focuses on desired status, rather than system outputs, and which recognizes the need to protect or restore critical ecological components, functions, and structures in order to sustain resources in perpetuity. (Moote et al. 1994, 1)

Definitions describe five principles central to ecosystem management: (1) socially defined goals and management objectives, (2) integrated holistic science, (3) broad spatial and temporal scales, (4) adaptable institutions, and (5) collaborative decision making. The actual practice of ecosystem management may be considerably less inclusive.

2. There is some irony in the historical evidence that early ecologists freely borrowed from the social sciences to construct key concepts. H. F. Cowles described “plant societies.” A. G. Tansley borrowed from Herbert Spencer to create his “organism-complex”; he in fact left ecology to study psychology with Sigmund Freud. A. Kerner reasoned from human communities to “plant-species communities”; Forbes to “communities of interest” between predator and prey. F. E. Clements was influenced by Spencer and sociologist Lester Ward. Both H. T. and E. P. Odum were influenced by

their father, H. W. Odum, whose sociological study of the American South (1936) was prescient in human ecology. For a review, see Golley (1993) and Hagen (1992).

3. Tansley's definition was exceptionally holistic and hierarchical.

But the more fundamental conception is, as it seems to me, the whole *system* (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense.

It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth.

These *ecosystems*, as we may call them, are of the most various kinds and sizes. They form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom. (Tansley 1935, 299)

E. P. Odum's definition was similar, though it included the proscription of human needs that

any entity or natural unit that includes living and nonliving parts interacting to produce a stable system in which the exchange of materials between the living and non-living parts follows circular paths is an ecological system or ecosystem. The ecosystem is the largest functional unit in ecology, since it includes both organismal (biotic communities) and abiotic environment, each influencing the properties of the other and both necessary for maintenance of life as we have it on the earth. A lake is an example of an ecosystem. (Odum 1953, 9)

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