Analyzing Human and General Ecosystems

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ANALYZING HUMAN AND GENERAL ECOSYSTEMS

By Michael D. Bradley*

The term ecosystem has become widely used by persons studying and discussing the interrelations between living organisms and the physical environment. Originally used to express the inseparability of natural communities and their environments, the term has proven to be equally applicable to species populations and, more recently, to human ecology.

GENERAL ECOSYSTEMS

The organizing forces of a general ecosystem arise from the stimuli of environmental influences and the responsiveness of living organisms to those influences. The ecologically significant environment, therefore, includes all those things, conditions, and processes, to which a living organism is sensitive and to which it is capable of reacting, including changes in the intensity and direction of stimuli.

The environment of a given place is the habitat of the organism. The effective external environment of an organism is never constant: plants and animals live in different habitats during different ontogenetic stages, and animals are inclined to move about. The plant-animal community has a certain generalized environment, in addition to its composition and structure, and is in fact composed of an array of different conditions of life, together with appropriate organisms.

Ecology is customarily concerned with the mutual relations between organisms and their external environments. It is in the environment that organisms find the natural conditions and raw materials which can be used to meet biological needs. These things and conditions are natural resources in a primary sense. The natural environment also contains things and conditions that are
harmful or detrimental to an organism's well-being and which must be avoided or counteracted if the organism is not to suffer ill effects. These may be called the *natural resistances*; some of the inimical conditions of environment are a product of the life processes themselves.

All life has two concurrent sets of determinants—the biological and the environmental—and no life exists at any level without their simultaneous interaction. The biological system is inherited and transmittable protoplasm, capable of self-replication. The environmental systems consist of that to which living substance is sensitive and to which it reacts. These interrelations can be grouped as actions, reactions and coactions.

Actions include all influences of the physical environment upon cells, organisms, communities and so forth. Examples of specific actions are the effect of light on photochemical reactions in plants and animals and the effect of temperature on metabolism. Interactions among physical factors of the environment have their consequences, as in the case of temperature change affecting saturation deficit of the air and, in turn, loss of water from plant and animal surfaces. Many stresses on living organisms are caused by physical conditions.

Reactions include all ways in which living organisms and their products change the physical environment. Reactions are also myriad. Examples include plant excretions which increase soil acidity, respiration which changes the carbon dioxide content of the air, and shading which affects temperature, light intensity, humidity and so forth.

Coactions include all of the interactions among living organisms; plant with plant, plant with animal, animal with plant, and animal with animal. Examples are found in competition for one or more life requirements, such as living space, and in food-chain relationships.

The central problems which the organisms of an ecosystem must work out are essentially two: the acquisition, use, transfer and dissipation of energy, and the acquisition, use, transfer and release of matter. These are phenomena commonly known as the trophic dynamics and mineral cycling of ecosystems. It is the solution of these problems by the biota which results in the organization of life into world formations, such as evergreen rain forests, grasslands, deserts, and tundra, and, within formations, the or-
ganization into the multitudinous associations found in the major biomes.¹

Ecosystems can be studied throughout the entire range from the unitary global one of the biosphere, to as small a space and as limited complexity as may be of interest, so long as the focus of attention is on energy and matter. Up to now no ecosystem has been thoroughly studied but the general outlines of primary production, subsequent trophic dynamics, and mineral cycling are known for some local woods of various kinds, grasslands, ponds, springs and coral reefs, and energy budgets and geochemical cycles are known within limits for larger world areas. From the biological systems' point of view more is known about the composition and structure of communities. In some cases the synusial structure has been analyzed, many niches identified, and food chains determined, but detailed quantitative data are generally lacking, especially for micro-organisms, reducers, the smaller consumers, and subteranean biota generally. To a considerable extent even qualitative data are absent.²

Human Ecosystems

When interest is focused on natural ecosystems as influenced by man, our experiences with nature are inadequate for complete understanding. Human dominated ecosystems have elements in common with all the others, and they reveal man's basic relations to nature and his ultimate inability to escape completely from the forces of nature; however, it is obvious that natural ecosystems in which man plays a strong and often dominant role are of a different order of complexity from the ecosystems of other species or combinations thereof. This is because man's powers in the ecological action system surpass all others, both quantitatively and qualitatively. Man has greater capacity to ameliorate and avoid natural actions; to react on the environment, changing it to make it more favorable to his needs and purposes, although sometimes producing serious environmental resistances; and his coactions with other species, including other men, can be either highly cooperative or competitive and destructive.

As mentioned previously, the resources of any living organism are the means of its existence, and they exist in the external and internal environments and the biological capacities of the organisms
themselves. For all organisms other than man it is sufficient to consider the natural resources and biological capacities; but in the case of man it is necessary also to consider his human resources. The distinction is important, and requires amplification. Man, too, has biological capacities; but man also has social capacities which far surpass those of any organism, and they may be epitomized by the single term culture. While the relations of man to other abiotic features of his environment are important, and his relations to plants and animals of his biotic environment are important also, the complex relations among men are paramount for man's ecology.

Although man must be concerned with energy and matter as they relate to his biological needs, his concern is not only for that which is physiologically based; it must also extend to his industrial uses of energy and matter. The problem, therefore, is to develop a conceptual framework of the human ecosystem that does no violence to general ecology but which at the same time permits a meaningful inclusion of human resources and man-made environment. An integrative model or scheme which accomplishes this purpose can be said to work as follows: man applies his labor, capital, and institutional resources to natural resources in order to gain the goods and services which meet his needs. If natural resources are the things and conditions of nature that man has not produced (no matter to what extent he has learned to make use of them), then human resources include, besides his strictly biological capacities, all that man has created, such as artifacts, systems and organizations, and concepts, ideas and values.

As to natural resources, in an elementary and primitive sense a rock becomes a resource if man uses it as a tool or a weapon; wood becomes a resource when he uses it as a digging stick, part of a shelter or as fuel; and an animal becomes a resource when man eats it or domesticates it for some useful purpose. In a more sophisticated sense, several metals in pure or alloy forms, plastics and ceramics become resources when they participate in complicated electronic devices. These examples demonstrate that man does something to or with natural materials to convert them to a useful state, for there is little in the environment that man uses directly as it exists in nature. The distinction becomes blurred between natural and human resources in regard to those human resources which are the physical means of production, that is, capital. The institutional resources also develop gradually from primitive social organizations, which are based in the biological necessities
of human reproduction and child care, to the multitudinous modern institutions which man has devised for cooperative effort. Finally, the concept of labor also shows development from simple human effort to modern, often complicated, personal contributions to the production function of the human ecosystem. In this usage, the production function includes every human contribution to the working of the ecosystem. These terms require further elaboration.

Just as the economist may lump all of the natural resources under the term land (because when economics was starting, land was the principal basis of wealth), so all of man’s personal attributes related to production can be lumped under the term labor. In this category the first consideration in terms of human resources is that of total population; within that, the entire producing sector has its own special significance. To know the size and proportion of the labor force in the total population, however, is to know little; it is also necessary to know the kinds and levels of skills and their frequency in the labor force. In addition, there are the sociopsychological characteristics of the people, including understandings, motivations and aspirations, their health and energy, their propensity to work, save, spend and invest, and succeed. Other attributes of the personal human resource include the entrepreneurial role, inventiveness, the propensity to accept or resist change, and the socioeconomic status and roles of technician, craftsman, professional, artist, and religious and secular leaders. A broad and vital input to the functioning of human ecosystems, comprised of all direct personal contributions to the working of the ecosystem, can thus be grouped under the concept of labor.

Under the term capital can be grouped all the physical means of production (as distinct from labor, the personal means of production) which have been created by man. In this use of the term, money as such is not considered capital, for interest is only in what money can buy; natural resources likewise are excluded, as land is a given in nature. Two categories of capital are recognized. First are the tools, utensils, implements, machines, factories, and so on, that are invented by man and are commonly owned privately by individuals, families and companies. The second category of capital is public, owned by government. Here is the social overhead capital, or infrastructure of the economy, that includes, for example, the hardware of the police and armed forces, roads, public buildings and monuments, and public lands, including
parks and forests. Capital comes into being when an individual or a society is able to produce a surplus. To use a primitive illustration, capital is created when there is a surplus of food which frees the time necessary to conceive and build a tool which in turn permits the production of more food. The return to capital is the increase in food over and above the original cost in food. Public capital, which is created from the surpluses of society, aggregated by government, is of two kinds. One contributes directly to the production function, or the working of the human ecosystem; the second kind of capital contributes to the aesthetic, religious or other features of society and affects materialistic production indirectly, if at all.

The third great and complex category of human resources is that of institutions, which men have invented as truly as they have invented machines. Under institutions is included all of the systems for cooperative human effort. Institutions are very diverse and often complex. They range from the intimate social structures of the family through the great organizations designed to further man’s interest in law, order, justice and government; business, manufacturing and commerce; education, communication, creative social and recreational activities; and religion. Institutions created for the cooperative efforts of participants can be used in competition with other social, political and economic groups.

It is necessary to distinguish institution, capital and labor. For example, the concept and organization of a vocational training school results in an institution, but as an institution it must be separated from the physical facilities utilized in training, which is the capital stock of buildings, machines, books, and so on, and, finally, the labor or persons (teachers and students) involved in the training. These three categories of human resources are universal.

**General and Human Ecosystems**

Natural ecosystems may be very complex. Human ecosystems have all of this complexity, plus the manifold human influences and capacities which are lumped under the concepts of society and culture. It is neither possible nor necessary to follow these ramifications very far, but a few further comments will help clarify the present thesis. Much can be learned from studies of natural eco-
systems that illuminate the functioning not only of them, but also the ecosystems in which man participates. However, ecosystems cease to be natural (unless one accepts the reasoning that human culture is biological) with human participation in their operation because contemporary man is such a strong and prevailing influence, especially modern industrial man.

Natural forest can be taken as an example of a complex ecosystem; it is interesting and fruitful to study its organization and how energy and matter circulate within it. A forest managed for sustained yield is something quite different because man seeks to have the natural productivity of the forest concentrated on a few selected species of one or more of the trophic levels of the ecosystem. In general, what man does in management is to simplify the natural ecosystem, without upsetting its inherent productive capacity, and periodically to withdraw from it products which are useful to him. In this case the harvested tree crops are primary producing organisms. It is the same with agricultural and horticultural ecosystems, except that human modification of the ecosystem is so great that fields of grain and orchards bear little resemblance to what would develop if man were to remove his influences. In animal husbandry man usually modifies a natural grassland or savanna or creates a pasture where forest or desert once were and harvests, from a different trophic level, the domesticated livestock which are secondary consumers of the original producing organisms. In fisheries man may harvest carnivores from a higher trophic level. Cheese and mushrooms represent harvests from the level of the decomposers. In all these cases man is still living fairly close to nature, whether he is a forester, lumberman, farmer, herder or fisherman. Out of the functioning ecosystems, from the human point of view, come economic utilities; the food (energy and matter) which sustains him, the materials which house and clothe him, and the energy and substance which support his industry. Urban industrial man seems far from nature, but this is a manifest delusion; although nearly all natural resources are under some degree of manipulation by the human resources, man's physiological needs must be met as must those of all life. The challenge to man, now and in the future, lies not so much in his technological ability to make the earth yield goods and services—by the skills of labor, the capital tools with which labor works, and the institutional systems with which he applies labor and capital
to natural resources—but in the overall management of his eco-
systems so as to maintain and even enhance their productivity
over time.

**ECOLOGICAL CONCEPTS**

An ecologist, in his complex analysis, develops many ideas which
are of great importance in assessing man's role in the human eco-
system. He first develops the idea of *interdependence*. In a field of
variables so closely and mutually interrelated, any change any-
where will, in some degree, affect the whole. Next, there are certain
*recurring patterns* in ecosystems, human and natural, which de-
mand attention. The most interesting, since it is the least obviously
expected, is the steady state. In a world of dynamic change, it is
constancy, not stability, that requires explanation; and ecosystems
contain a number of patterns which preserve themselves over sub-
stantial time periods with little apparent change. Ecology, however,
also recognizes change in the form of an increase or decrease in the
magnitude of one or more variables in an ecosystem. Decrease is
self-limiting, and increase is also found to be self-limiting. The
period of increase is usually succeeded by a period of steady state;
or by a reversed trend, usually resulting in an oscillation; or by a
crash, in which the increase, often accelerating, is terminated by a
sudden or radical alteration of the ecosystem. The first occurs
for example, when a local bird population is stabilized by a limi-
tation of suitable nesting sites, or when the number of lawyers in a
small town is stabilized by the number of prospective clients. The
second is exemplified by those linked oscillations in the numbers of
prey and predators which have often caught the notice of ecologists;
the lynx and the snowshoe hare in the arctic tundra are a familiar
example. Finally, the ecologist develops the concept of *regulations*.
When the steady state is observed, the forces interacting in the
ecosystem are so disposed that any departure from the steady state
tends to change the balance of forces in such a way as to reverse the
departure. When oscillation is observed in an ecosystem, the span
of oscillation defines either the degree of displacement needed to
trigger the change which will reverse the process, or the temporal
lag before the reversal can become effective. An increase or de-
crease generates regulative forces which will prevent its continu-
ance in one or another of the familiar ways. The delicate, mutual
balance which exists in every ecosystem has been much studied in
recent years and periodically attracts the notice of the public, whenever some human intervention with nature, such as an insecticide, has unlooked-for repercussions.

The idea of balance, or homeostasis, has been made much clearer by the study of ecosystem processes. Whenever the interaction of creatures in a community is fairly constant, their numbers and their ways of life are adjusted to each other and to the environment in a balanced manner. Whenever one variable changes, it sets in motion other changes which tend to restore the previous position.

Thus, mutually adjusting ecosystems exemplify dynamic homeostasis. They have sought and found their own stability and, if disturbed, they will seek it and ultimately find it again. This power is not confined to organic ecosystems. Self-stabilizing mechanisms, like the automatic controls of guns, show the same propensity; and the engineer's term "feed-back" has come into general use to describe the principle on which it works. Ashby has described the theory in completely general terms, analyzing the meaning of stability and the conditions in which variables that respond to each other arrive at a homeostatic balance and preserve it by continuous mutual adjustment. These ideas provide a language and a model which makes easier a discussion of progress. If the process of human interaction with the environment is a special case of something more general, it may be easier to see in it what is peculiar.

The main peculiarities of human beings, in terms of their human ecosystems, are two. First, they have extraordinary and growing powers on the one hand to use science to predict the future course of events, and on the other hand, to use technology to alter it. These two abilities are likely to have opposite effects. The first should make man the most adaptable of creatures; the second makes man the least ready to adapt, for, when he encounters a physical or biological limitation, he tends not to adapt to it but rather to alter the limitation. For other creatures the natural environment is a constant or an independent variable. For man, the environment can be affected, instead of the reverse, and he does so on larger scales; this is often done on purpose, and still more often by accident. This capacity is a recent characteristic of a small minority of the earth's inhabitants: modern, urban man. This habit appears to be becoming more general.

An ecosystem containing creatures who deal with limitations in such a way will not stabilize as other systems do. Other creatures develop homeostasis within a framework of limitation. Modern
man changes the framework to suit himself and is proud of it. He seems to believe that he has escaped from the stable into an expanding world. He needs not adapt to the environment, so long as he can adapt his environment to himself. Moreover, some cherish the illusion that every conquest of the environment leaves less to conquer in the future, that every increase in power is an increase in control. During two expanding centuries man has developed an implicit belief that the process is an expanding one always calling for a further exercise of human domination over the environment; and that the corresponding ethic of dominance over nature is courageous and noble, while accepting limits is cowardly and base.

This may have been a natural, but nevertheless mistaken, view of nonenvironmental relations in an expansionist age. It is clearly an inadequate guide to social life, since an expansion of one human over another's environment sets each other's limits to an ever greater degree. The idea that freedom means to be without limitation rather than to choose limitations is a dangerous misconception for the overcrowded inhabitants of a small, self-contained life support system, the planet Earth.

Unfortunately, at this stage of human evolution, man's powers are great in comparison to his meager understanding of the fundamental and inescapable functioning of ecosystems, and in many instances man is diminishing the productive potential of his environment. All too often the apparent wealth-producing use of nature is misleading and short-sighted; for it is based on the consumption of natural-resource capital (as in accelerated soil erosion and loss of soil fertility) in the pollution of air, soil and water by the waste products of industrial and urban life. The virtue of the ecosystem concept is that we are made to see the general in the particular. Only a wider understanding of ecology, especially as acquired through knowledge of ecosystems, may permit man not to return to nature but to manage his affairs so as to produce liveable human environments.

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FOOTNOTES

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