1991-01-01

Ecosystem Approach: Theory and Ecosystem Integrity. Report to the Great Lakes Science Advisory Board

Great Lakes Science Advisory Board. Ecological Committee

International Joint Commission

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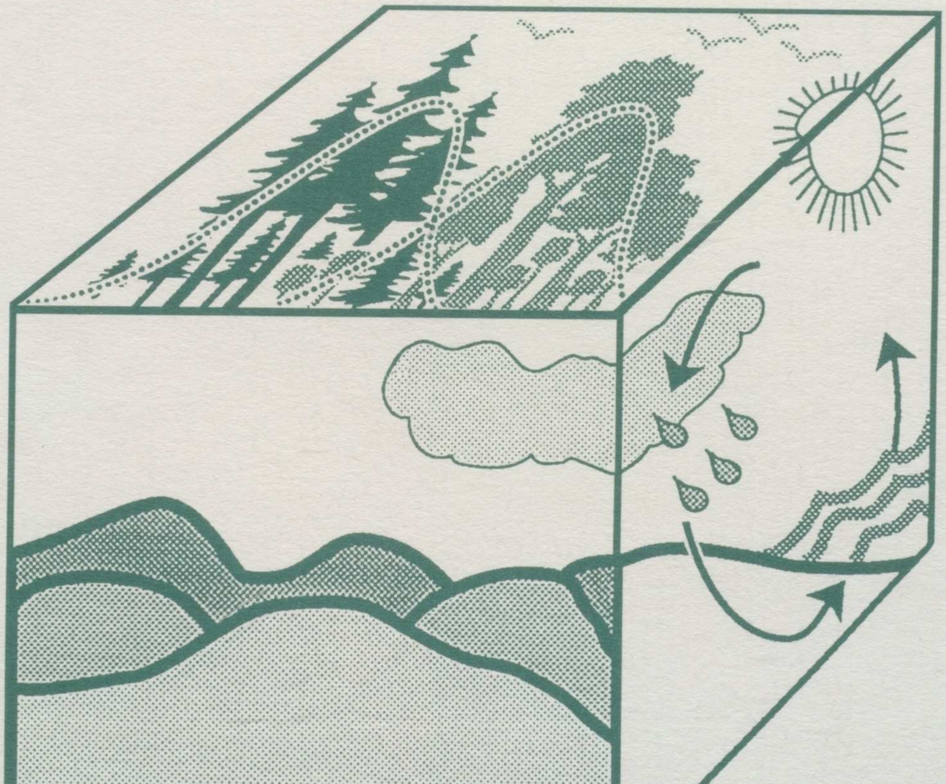
The Ecosystem Approach:

Theory and Ecosystem Integrity



Timothy F. H. Allen,
Bruce L. Bandurski,
and Anthony W. King

International Joint Commission
United States and Canada

Report to the Great Lakes Science Advisory Board

THE ECOSYSTEM APPROACH:

THEORY AND ECOSYSTEM INTEGRITY

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ISBN 1-895085-78-0

Printed in Canada
on Recycled Paper

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DISCLAIMER

This report was carried out as part of the activities of the Ecological Committee, pursuant (in the 1991 fiscal year) to Project No. 32.1.4 of the Great Lakes Science Advisory Board's Workplan and Budget. While the Board and the International Joint Commission supported this work of the Ecological Committee, the specific conclusions and recommendations do not necessarily represent the views of the International Joint Commission, U.S.A. and Canada, or the views of the Board or the Board's other committees or working groups.

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Acknowledgements

We wish to thank Willow Ealy, who put up with the long process of draft and revision in a spirit of great tolerance. She is responsible for the layout of the text herein. Special thanks go to Kandis Elliot for drafting the figures. Early drafts of this document received detailed review from a large number of colleagues and we are grateful for their help.

The authors of this report acknowledge the community known as the Great Lakes Basin Ecosystem for the accommodation and mutual support which brought about and sustained this endeavor.

Part of this project was supported by National Science Foundation Award DEB 921 5020 to Allen through the University of Wisconsin.

In my beginning is my end . . .

Trying to learn to use words, and every attempt
Is a wholly new start, and a different kind of failure
Because one has only learnt to get the better of words
For the thing one no longer has to say, or the way in which
One is no longer disposed to say it. And so each venture
Is a new beginning, a raid on the inarticulate
With shabby equipment always deteriorating
In the general mess of imprecision of feeling,
Undisciplined squads of emotion . . .

Home is where one starts from.

— T. S. Eliot, "East Coker" in Four Quartets

1.0 INTRODUCTION

> ***Progress in continuing to restore and enhance in perpetuity the quality of boundary waters in the Basin, hinges on adoption of an ecosystem approach that includes a biospheric perspective. ...***
>
> ***In our opinion the single most serious difficulty in melding the water quality objectives approach and ecosystem approach may be in overcoming past habits associated with a water quality objectives approach. In a water quality objectives approach the minds of government administrators and potential violators tend to become imprinted on "15 milligrams per liter" rather than on the requirement for restoration and enhancement of the quality of boundary waters in perpetuity. ...***
>
> ***It should be clear that implementation of the proposed ecosystem approach must extend beyond the advisory role of the Commission into management structures on both sides of the border. The essential feature of the ecosystem approach is integration. No single agency or organization can presently lay claim to following an ecosystem approach because, by definition, the approach calls for orchestration.***
>
> ***-- Great Lakes Research Advisory Board, The Ecosystem Approach: Scope and Implications of an Ecosystem Approach to Transboundary Problems in the Great Lakes Basin. Special Report to the International Joint Commission, presented July 1978; pp. 31-32.***

This overview report is a revision and extension of the 1978 report, The Ecosystem Approach, from which the foregoing quote was extracted. That was a special report to the International Joint Commission from the Great Lakes Research Advisory Board [now the Great Lakes Science Advisory Board]. It served its purpose well, catalyzing the shift from a narrow perspective of water in a political context to a wider perspective and significantly different approach of policy development in an ecosystem context. This 1993 report is but an effort to incorporate what has been learned in the past decade or so. It, too, will be succeeded as participants gain knowledge and understanding.

Nearly ten years ago, the understanding of the phrase *ecosystem approach* was well summarized in "Ten Ecosystem Approaches to the Planning and Management of the Great Lakes", by Brenda J. Lee, Henry A. Regier, and David J. Rapport, published in the Journal of Great Lakes Research. In 1985, National Academy Press published The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management, a joint product of The Royal Society of Canada and the National Research Council of the United States of America. In a section entitled "Definitions and Boundaries of the System" the RSC/NSC report concluded that "the language used in phrasing the purpose of the Agreement should be interpreted comprehensively." Too often, discussions about implementing such parts of the Agreement as Annex 2 (Remedial Action Plans and Lakewide Management Plans) have moved to focus more on piecemeal specifics and less on the general principles. One purpose of the present document is to anchor the Ecosystem Approach in general principles that encourage comprehensive interpretation of the Agreement.

> The language expressing the Agreement's purpose is comprehensive:
> *The purpose of the Parties is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem. In order to achieve this purpose, the Parties agree to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes System.*

We have used the above quotation from the Agreement as guidance in this revision of The Ecosystem Approach, but our concerns about ecosystem integrity go well beyond system alterations that are caused by chemical contaminants commonly called "pollutants".

Plans developed pursuant to Annex 2 "are to serve as an important step ... toward restoring and maintaining the chemical, physical and biological integrity of the Great Lakes

Basin Ecosystem." The Parties' use of the term "restoring" is evidence that their concern for integrity includes more than just an accommodation to a new system state or to a new level. Restoration of integrity includes such activities as wetlands conservation to keep and restore habitat for diversity of organisms and their reproduction [cf. Annex 7, Annex 13, and Annex 17 of the Agreement]. This is not simply a restoration of or return to some desired earlier system state. It is more aptly characterized as achievement of a new and desirable highly-integrated state, that accommodates to events of the past. In the new state the rehabilitated system is resupplied with the means for healthy life, but it is not the pristine system born anew.

There is always tension in the language when a new idea is to be expressed. On the one hand, there is a need to use words which are generally understood in usages which are commonly accepted. On the other hand, there is the need to develop new terms and new usages to distinguish what is new from the shared understanding that prevailed before. Such is our dilemma in talking of "the ecosystem approach". Whatever terms we use carry the baggage of their varied histories.

The horns of our particular linguistic dilemma are especially uncomfortable because the problem appears deceptively innocuous. In the phrase "the ecosystem approach", our difficulty is not with the word "ecosystem", nor with the word "approach". The problem is "the". Do we continue to use the critical phrase and risk perpetuating a common misunderstanding embodied in it, or do we invent a new phrase and confuse the issue in a different way? We choose the former but explain the prevailing misconception at this point.

The convention in the Great Lakes Basin is to talk of "the ecosystem approach". However, the phrase refers not to "the ecosystem" but to "the approach". It is <u>the</u> approach to <u>an</u> ecosystem -- not the singular ecosystem. Make the phrase plural and study "ecosystem approache<u>s</u>" and we have the same problem as if we used the phrase "an ecosystem approach". Both leave the incorrect impression that any approach will do, that there is no rigor, and that any point of view is acceptable.

The ecosystem approach, as asserted in this document, insists upon rigorous definitions of ecosystems. It also demands unambiguous linking of various ecosystem conceptions of different types and sizes, all explicitly defined. The ecosystem approach rejects the notion that there is one ecosystem conception that we can use for all purposes. There may be one material world but, as we shall lay out in the body of this document, only orchestrated sets of different points of view can capture its richness adequately[1].

So, "The Ecosystem Approach" it must be, but only with the caveats raised above.

> *In practice ... ecosystem approach means ... that management for the lakes should evolve in response to a growth in understanding of the factors that influence the quality of the environment within the Great Lakes Basin and determine the quality of the waters that unify the ecosystem and define its boundaries. More needs to be learned, but the major problem now is how to mobilize the political will to move ahead with the task.*
>
> *-- Lynton K. Caldwell, "Introduction: Implementing an Ecological Systems Approach to Basinwide Management", in Perspectives on Ecosystem Management for the Great Lakes: A Reader (1988)*

2.0 The ECOSYSTEM APPROACH

The term "ecosystem approach" was introduced in the present context in the 1978 Great Lakes Water Quality Agreement. Although the approach was first named and recognized as important by environmental scientists, it also has an intuitive appeal.

It is fair to ask, "An ecosystem approach to what?"

There is a material system in the general region of the Great Lakes consisting of water, air, minerals, biota in general, and humans in particular. For us to deal with it, a boundary for that system must be erected each time we change our question or perspective. Only then is it clear what is to be included inside (the system's parts) and what is to be seen as outside (the system's environment). Furthermore, inside that boundary, some aspects of the system have to be identified as parts, an aspect of system structure, so that other aspects of the system may be seen as process related to the behavior of those structural elements. An important phase of the "ecosystem approach" is that sequence of system delimitation and definition.

2.1 Defining A System

There are clearly many ways to delimit the Great Lakes Basin Ecosystem system and divide it into parts. Some guiding principles are most desirable. In the ecosystem approach there is not one material ecosystem to which our definitions must conform. Rather, the human actor must accept responsibility for erecting definitions and be prepared to change them when the purpose of the description changes. Definitions are not correct in and of themselves, but some are more useful than others. Those chosen wisely lead to effective human decisions. Since we must erect a system boundary at the outset, it follows that there is not one ecosystem for us to address, but rather we choose an operational ecosystem for the question at hand.

Implicit in a question is a definition for the system. Scientific truth only applies within certain defined regimes, and the use of specific questions makes those definitions explicit. Good science is consistent within the defined frame, but the best science has a particularly powerful set of definitions implied by the questions it asks. The cliche is that science is not about finding answers but is really concerned with finding good questions. If you want important answers you have first to ask important questions.

The use of specific questions can lead to a certain sterility when the specificity of the question is taken to mean narrowness of focus. One of the reasons the ecosystem approach was created was as an antidote to scientific tunnel vision. Scientific activity which is too narrowly focused cannot serve when we must deal with large complicated issues involving real people living in a rich environment. The specificity of a scientific question relates to its explicit nature, not the narrowness of its scope. In the ecosystem approach, the effort is to achieve appropriately expansive questions so that the system becomes defined to be particularly inclusive.

There are two separate considerations with respect to the nature of the boundary of ecological systems: system scale and type. Until recently these have been confused, even in the academic literature of ecology. First there is the *scale* in time and space to which the boundary applies. In general, spatially large scale things take a long time to exhibit changes in behavior, while fast, ephemeral entities are usually small in size. Thus scaling in time and space are often related. The size of the bounded system determines the appropriate spatiotemporal scale of the observation scheme, the scale of the pertinent data.

Second, and not to be confused with scale, are considerations of the *type* of system that is bounded. Independent of scale, there are criteria that set the bounded system away from its background. The bounded system is the foreground and its boundary is a reflection of the type of system it is. One has to look at the appropriate scale to see an object, but which object one sees in the foreground at a certain scale comes from the standards that prescribe the type of system.

Let us turn to a concrete everyday example. In the Great Lakes Basin a town might be delimited on grounds of political boundaries, on the area serviced by the sewage treatment plant, on grounds of the local economy, or as a habitat for an urban creature like the house sparrow (Figure 1). All four of these town systems may be in approximately the same place and occupy the same general area, but the exact position of the boundary will depend on which type of system one defines.

Note that the type of system comes from the question that is asked. For example, "Is the town economy healthy?" brings into play a boundary different from the question, "Is the treatment plant adequate for the town at this time?" Yet another more inclusive boundary might be needed for the question, "Is the treatment plant big enough to handle expected economic development?"

The nature of the parts and the relationship between them is what gives the qualities of the whole. The town as an economic unit has property tax payers, businesses, and other economically defined contributors linked together by various economic instruments, such as money. The town as defined by its sewage treatment plant has units generating waste linked by sewers to the treatment plant.

Notice that people living in the town play a role in both systems by both paying taxes and using water. The two roles need not be competitive. It is possible to link those activities, say as the owner of a car wash business generates large quantities of waste water. When viewed in that manner, the car wash proprietor is now a part of the economic development/treatment plant system which was erected as the system for dealing with the ecology of local economic development.

The material system (which includes the town, its buildings and infrastructure, its institutions, and its people and other biota) can be defined in an infinite number of ways. It depends on the purpose at hand as to which type of system it becomes. For a given purpose, there are more and less effective ways to specify the system. The ecosystem approach recognizes that some of the ways we have defined the ecosystem before now have been less powerful than they might be, given the problems we wish to address. Notice that even less

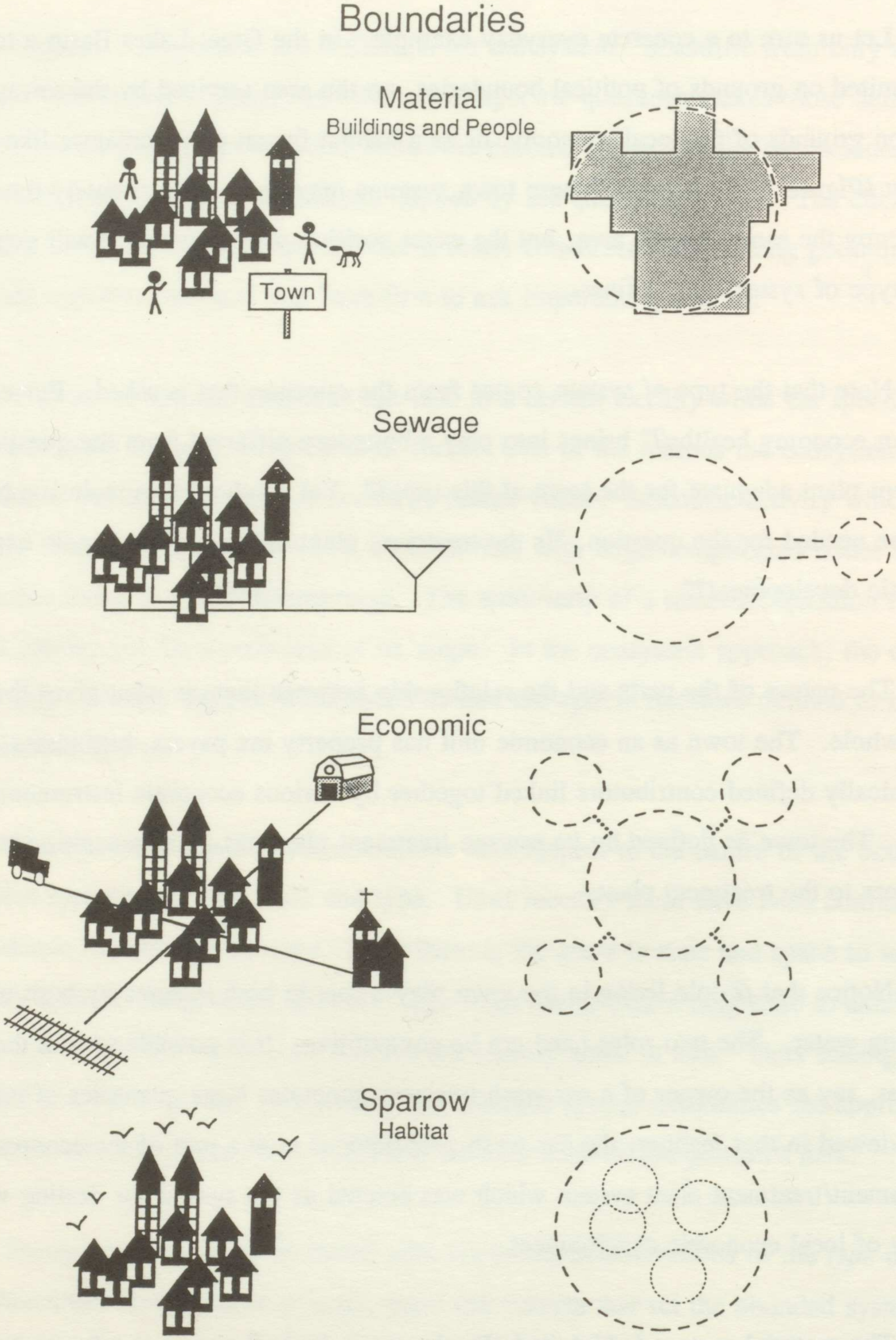


Figure 1. The same town, made of the same buildings, may be viewed in many different ways so that alternative relationships between the parts are recognized. While the boundary of the town is basically in the same place for each way of looking at it, the sewage system, the economic system, and the bird habitat town all have slightly different boundaries. The major components that make up the town as well as the critical connections inside the town are also different for each point of view.

effective ways of looking at the ecosystem are not wrong in principle; rather they might divide parts which could be seen more clearly as united to form a single working unit. These inappropriate divisions can arise either from traditional lines of division used for separating academic specialties (like sociology as opposed to ecology) or from lines of administrative jurisdiction (like city limits) to name just two sources.

It emerges that we need new interdisciplinary ways of defining the system and specifying its parts. Perhaps we even need new disciplines altogether. The ecosystem approach involves finding helpful non-traditional boundaries that might well include material from several academic specialties as well as from non-academic sources. The approach then uses those boundaries to define the system in a new way that might well lump or divide political units as is appropriate.

2.2 The Richness Of The Ecosystem Concept

In the first formal IJC document explaining the ecosystem approach[2], there was a reference to a style of thinking that was captured in the distinction between the notion of house versus home. The ecosystem approach sees humans living in the biosphere as a home rather than the planet being the house of man. The word "home" evokes a much richer setting than does the word "house". "House" is a useful but mundane word. It conjures up nothing more than a tangible structure, a building of a particular type. Note that a house has a particular set of dimensions; it can be well described by something as sterile as a realtor's listing. Thinking of the ecosystem as a house could lead to the sterile narrowly-focused view -- the inflexible science wedded to a limited set of definitions that we wish to escape.

The word "home" is an entirely different matter. A home is something very evocative. It is a rich concept.

First, there is a caring for a home that transcends the mere monetary value of a house. Homes often involve a group of people who live together and jointly take care of and relate to their home. Selling a house is a relatively easy, painless activity; but leaving home can wrench one out of an important personal reality. Thus home has more meaning than house because we care about it more. There is a distinctly ethical facet to the ecosystem that is captured in the notion of the ecosystem as our home. The commitment to finding powerful definitions is so that we can keep our home safe.

Second, the richness of scale of home is important. Note that we leave home in the morning to go to work. An army base may not be home, but when the troops leave it to go to war, we wish them safe passage back home. Thus home can mean a house, a home town, a country; furthermore it can mean all of those things to just one person all at the same time. An astronaut leaves the home to go to the launching facility, and shortly thereafter may leave the planet, which is also home (Figure 2). There are many scales at which the notion of home operates; there are many scales at which the ecosystem approach addresses the Great Lakes Basin Ecosystem. By separating system scale from system type it is possible to invoke several scales without becoming confused.

Also the notion of home has a richness of type. At a given scale, many different types of building can constitute home, albeit for different people. Home might be a house, an apartment, or a houseboat -- each being the dwelling place of a particular person -- without any contradiction in the use of the word (Figure 3). The ecosystem approach insists on a willingness to accept different types of system, each with its own purpose, as in the case of the town economy and the town sewage district. Thus, the ecosystem approach requires a flexibility of thought that is absent in the hard science, discipline-restricted approach to problem solving that has prevailed before now. Thus the notion of home as a scale-independent and type-rich notion also applies well to the concept of ecosystem embodied in the ecosystem approach.

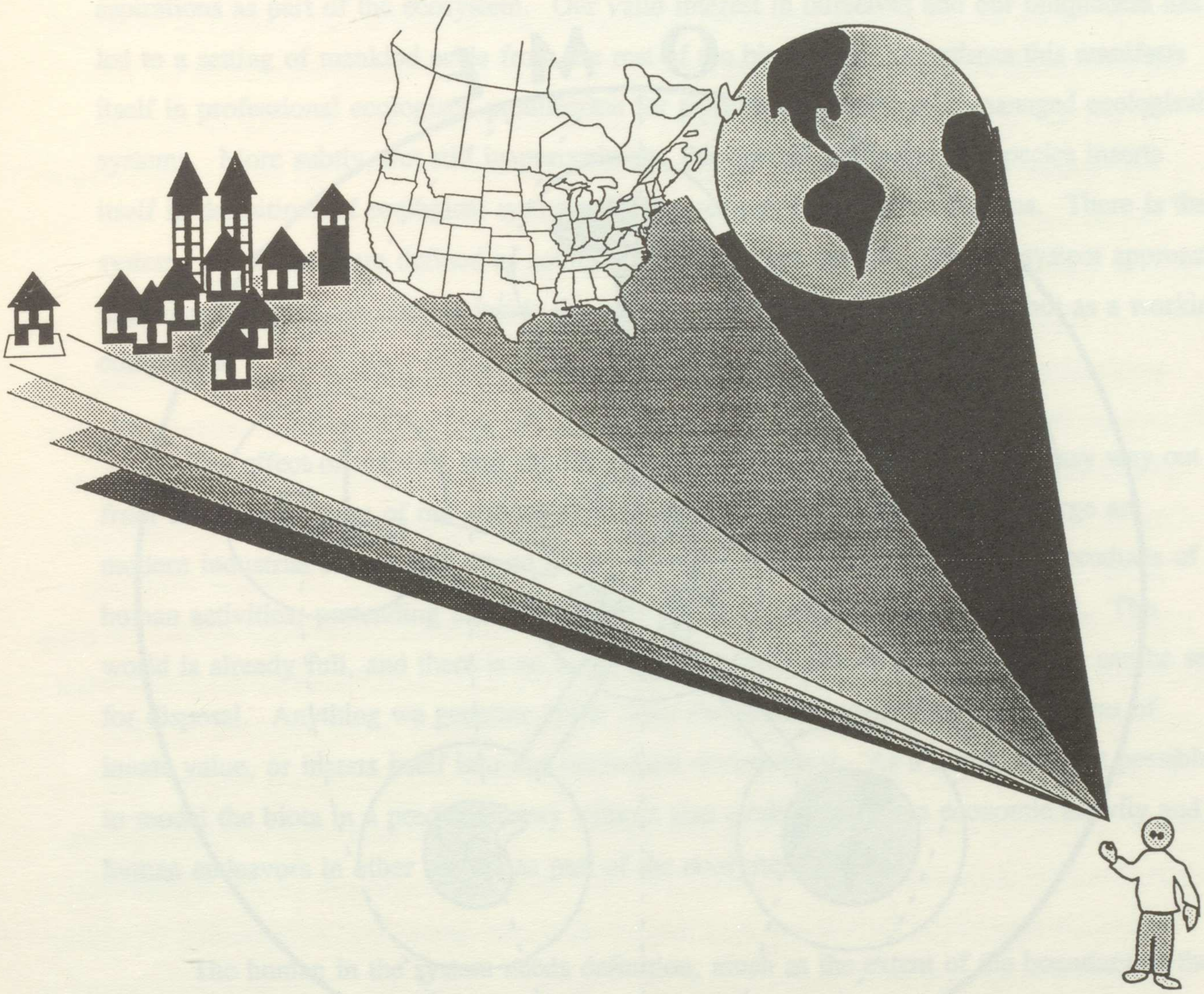


Figure 2. The concept of "home" is rich with respect to scale. Homes can be large or small, all the way from the Earth, our home, through a home country or region, and a home town, to a single dwelling. For all those scales of home, there is a critical facet of it being the place, large or small, in which important parts of life are lived out. The ecosystem is a place where humans and other creatures go through the process of living, and that is what makes it an evocative "home."

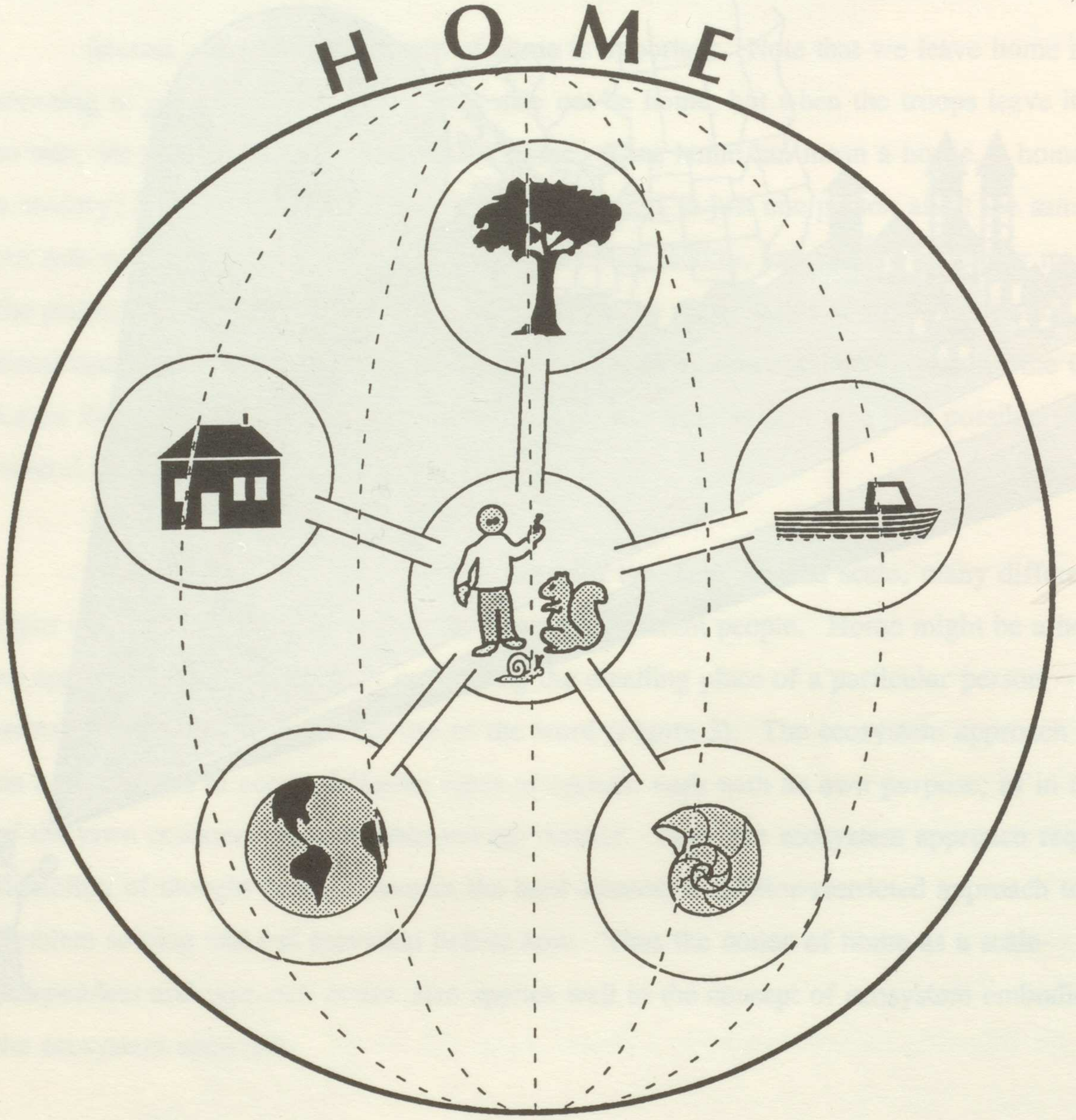


Figure 3. Home is a rich type of place. There is no contradiction in various people dwelling in homes of very different types. Animals make their homes in yet a more diverse collection of structures, from forests to snail shells. Different organisms in the ecosystem make it their home in many different ways, and a fully effective way of approaching ecosystem problems must be cognizant of that richness.

2.3 The Human Being In The Ecosystem Approach

A critical characteristic of the way the ecosystem approach defines the Great Lakes Basin Ecosystem is the active inclusion of the human creature with its technology and aspirations as part of the ecosystem. Our valid interest in ourselves and our uniqueness has led to a setting of mankind aside from the rest of the biosphere. Sometimes this manifests itself in professional ecologists' predilection for pristine wilderness over managed ecological systems. More subtly, but still inappropriately, this special status for our species inserts itself in definitions of ecological systems that are seen as impacted by humans. There is the system, and humans are defined as acting upon it from the outside. The ecosystem approach unequivocally puts our species inside the system, not as an outside influence but as a working component.

The effect of insisting that we are part of the system is to prohibit any easy way out from the consequences of our actions as individuals and as a civilization. So large are modern industrial effects that we no longer have the luxury of ignoring the end products of human activities, pretending that the biosphere is large enough to absorb them all. The world is already full, and there is no longer a somewhere else to which our waste can be sent for disposal. Anything we generate either takes the place of something else that was of innate value, or inserts itself into our immediate environment. As a result, it is not possible to model the biota in a predictive way without also modelling human economic activity and human endeavors in other sectors as part of the ecosystem at large.

The human in the system needs definition, much as the extent of the boundary of the town used as an example in the previous section required definition. Remember how there was not one correct definition of the town limits, but an indefinite number of them possible, four of which were raised as different examples, each with its own purpose. Similarly humans can be defined many ways according to the roles they play in the ecosystem. This much seems certain: defining humans only one way is as inadequate as only one definition of the entire ecosystem. The human being can be profitably seen cast in the following paragraphs as three major characters in the Great Lakes Basin Ecosystem although this is a far from complete characterization for a creature as rich in complexity as we are. These characterizations of the human creature were used as examples in the previous document explaining "The Ecosystem Approach."

First we are very much biological creatures, and as such we are subject to biological insults along with other species in the Basin. If for no other reason, we need to be concerned for the welfare of other species because our own biology is based on the same biochemical pathways. An insult to them is the same insult to us. This facet of ourselves is the human animal.

The second role is that of the socially-conscious and self-aware human. We are particularly poignant in this role. As individuals, it is here that we love, and think, and enjoy. In groups we indulge in culture, politics, and a host of other social activities. This is the facet of ourselves that is captured in the word "humanity." The scientist who claims to know what is best for this human is preposterously presumptuous. It is for this reason that public involvement is part of the agenda of the ecosystem approach. Of course there are parts of remedial action that require decisions based on technical knowledge beyond the grasp of the lay public, but this should not be used as an excuse to disenfranchise the public when their opinion is as valid as that of the experts.

Enormously powerful in ecosystem function, is the third actor, the economic human. For an anthropologist, the economic human might be acceptable as just part of the socially-conscious human, but for our purposes the economic human needs to be identified separately because it plays such a distinctive role in contemporary ecosystems. This economic human is the one that supports the standard of living, the powerful one that needs to be watched carefully by the other two. Without giving economic theorists carte blanche, we must appreciate that it is the economic base that allows us the luxury of the time to even think about the ecosystem approach. There is no retreat to the noble savage; we need to maintain a viable economic system if we are to avoid unacceptable human suffering. It is the economic human who, if successful, will support a long term viable ecosystem, paying for remedy as necessary, implementing controls, and recycling so that a good life in a sustainable ecosystem is possible.

At least all of these humans must be considered at once if there is to be any workable accounting of the critical structures and processes in the Basin. Many other facets of being human will be required to address the critical problems of the Great Lakes Basin Ecosystem. These would include the ethical, religious, philosophical, or artistic human and many more. Each problem invokes a different multifaceted human resident in the ecosystem (Figure 4).

2.4 The Technical And Lay Meanings Of "Ecosystem"

Earlier in this report we turned to see how scientists construct and bound models as a precursor to examining the difficulties of framing something as rich as an ecosystem in the ecosystem approach. We have still not turned to deal with the concept of ecosystem specifically. At this time it is helpful to return to how scientists have dealt with the specific concept of ecosystem, as a precursor to the wider view of the ecosystem embodied in the ecosystem approach.

In the mid-1930's Sir Arthur Tansley[3] coined the term ecosystem. While he might not now recognize what we have done with his original conception, it is worth looking at the roots of the idea. Until Tansley wrote his classic paper, ecologists almost universally viewed their subject as organisms in a physical setting. This is not an incorrect view, but it does miss some important aspects of nature. Tansley took the same physical system and viewed it such that the abiotic, physical environment was now inside the system. At the time it did not seem such a radical departure, but it led to a completely new way of studying ecology.

With the physical part of a forest (e.g., the soil and the atmosphere) as part of the system, suddenly new highly-structured aspects of nature emerged. It was known that trees require minerals and that they take them from the soil. Less understood was the remarkable tenacity with which the forest preserves its store of nutrients, not just using them again and again, but allowing almost none of that store to be washed away. Nutrient cycles, as they came to be known, became recognized as highly structured pathways in nature albeit unseen. Some two hundred years earlier, Linnaeus had talked of "the economy of nature,"[4] but what emerged here was an accounting system of impressive efficiency.

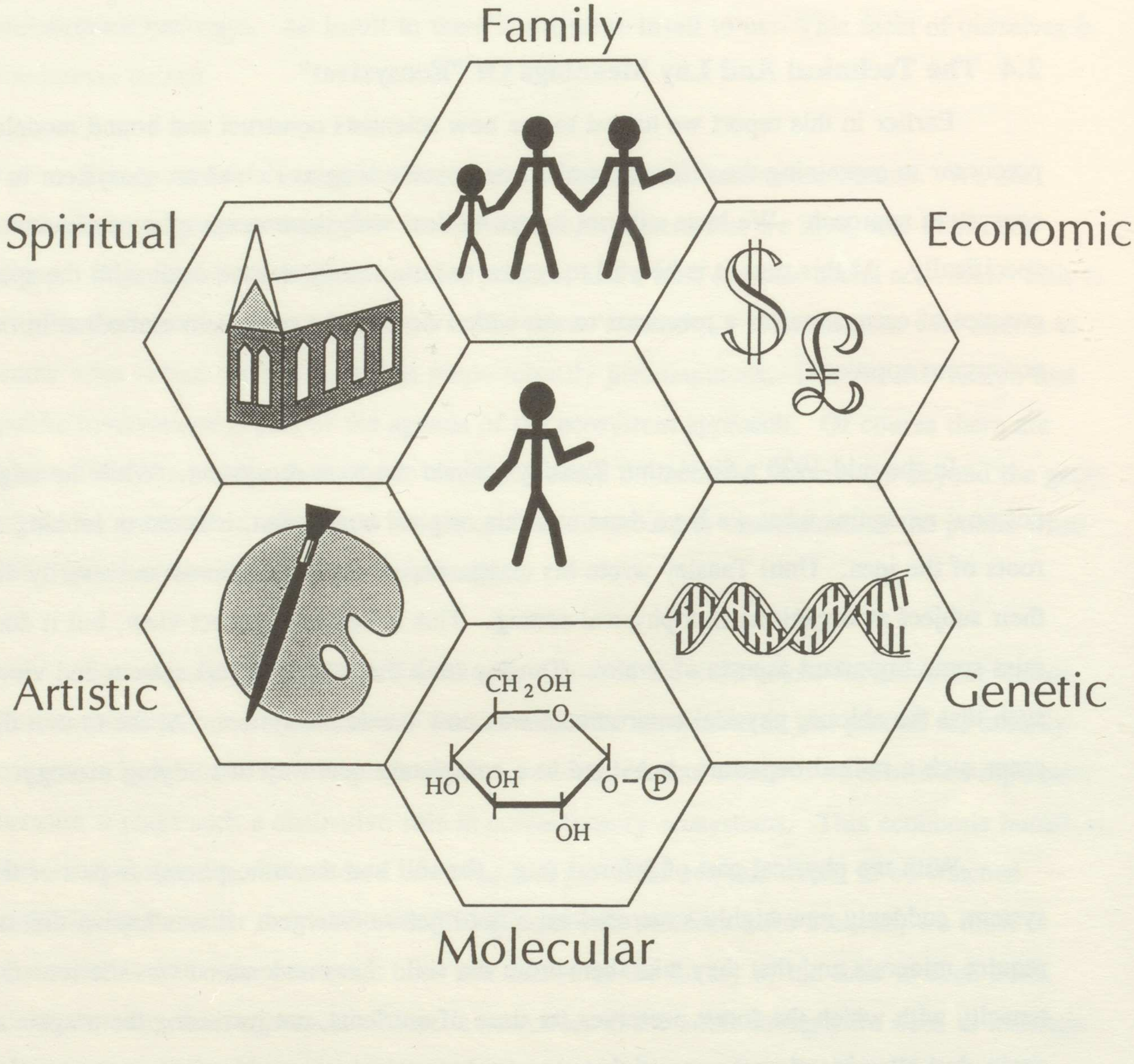


Figure 4. The same human being can play diverse roles in society and the ecosystem, and live in it according to many criteria. Therefore, humans at large are a richly multifaceted part of the ecosystem.

Once ecologists started to think in these terms, other networks of flow through ecosystems received attention. Food chains were described and the energy flows were given an accounting -- as animal eats plant, and then animal eats animal[5]. As more data were collected, it appeared that a food web was a more appropriate conception. Out of all this came a realization that there were a lot more connections in ecosystems than we had suspected. The notion that everything is connected to everything else finally had data to back it up.

The word "ecosystem" has become part of common usage. It enjoys many shades of meaning. This is hardly surprising because, even in the literature of professional ecologists, the concept of ecosystem is both widely understood and "diffuse and ambiguous"[6]. Let us consider the origins of the term and its prevailing use among environmental scientists. This should give insights to the common usage of the term as well as the special meaning of the word at the interface between scientists, politicians, administrators, business, and the public in the phrase "ecosystem approach."

To professional ecologists, *ecosystem* is often used loosely to refer to the collective ecology of some location or area. The ecosystem may be specific or generic, referring to a particular ecosystem or some ecosystem type. There are references to the Cedar Bog Lake ecosystem[7], the Isle Royale National Park ecosystem[8], Great Lakes ecosystems[9], the Hudson River ecosystem[10], the Serengeti ecosystem[11], southeastern [United States] ecosystems[12], forest ecosystems[13], tropical rain forest ecosystems[14], an oak ecosystem[15], and a *Populus tremuloides* ecosystem[16]. Puzzling as it might appear, the ambiguity in the use of ecosystem is understood reasonably well, and *ecosystem* is a useful handle for referring to a wide variety of ecological conceptions of a wide range of different material systems.

Ecosystem was first defined as the collection of all the organisms and environments in a single location[17]. However, it has also come to mean other things, even for professional ecologists: 1) any organizational unit including one or more living entities through which there is a transfer and processing of energy and matter[18], or 2) a system, a collection of interacting components and their interactions, that includes ecological or biological components[19]. Interactions in this last conception of the ecosystem are frequently through transfers of energy and matter[20]. Common to all these definitions, and at least implicit in the general usage described above, is the idea that the ecosystem includes the physical environment in addition to biological components (e.g., organisms).

2.5 Ecosystem Dynamics And Structure

Strongly associated with the concept of ecosystem is the concept of *ecosystem process*. Ecosystem process generally refers to the functioning or operation of the ecosystem, its integrated holistic dynamics. It is commonly associated with the dynamics of matter and energy processing and transfer. Biomass production and nutrient cycling, for example, are often called ecosystem processes. We will need a more flexible and inclusive definition of ecosystem than one that considers only material flows for solving ecological problems in the Basin at large. However the emphasis on connection through dynamic interaction of parts comes to a degree from the technical focus on matter and energy flow of discipline-centered ecosystem scientists.

The concept of ecosystem function is implicit in the general use of ecosystem to refer to the collective ecology of a given location. The term ecosystem is invoked particularly when attention is given to dynamics between living things or between them and their environment, and not just simply the area's living things as a mere collection. Consider the reference to *forest ecosystem*, for example, rather than simply *forest*. Minimally, use of ecosystem in this context implies a consideration of both the biota and physical (abiotic) environment of an area. There is also an emphasis upon the dynamic interactions between different living things as well as living and non-living material in the area in question when "forest ecosystem" is the term employed.

The word function has several meanings in ecosystem science, and we need to tease them apart. First there are the dynamical connotations where an ecosystem or ecosystem component functions to show behavior, perhaps a turnover rate. For example, by some definitions the below ground carbon storage unit consisting of roots, soil organisms and organic matter, and carbonate functions slowly. The other meaning of function is structural, and implies a role. For example, the function of the green leafy part of the ecosystem is to capture sunlight energy in photosynthesis. This is much like the role of an organ in a body. The role of the human heart is to pump blood; that is its function. It also functions at 70 beats a minute, but that is its dynamical functioning.

Despite the attention given to process (sometimes called function) in the ecosystem concept, it is possible to talk about *ecosystem structure*. The issue of structure was raised earlier in this document. Remember that structure is what emerges in the act of defining, bounding, and decomposing the ecosystem. These decisions about the system are related to the material ecosystem such that ecosystem structure commonly refers to the distribution of matter and energy among system components. While the connections between structural components may involve dynamical fluxes, the regularity and persistence of the connections among components are also part of ecosystem structure. Because of the emphasis on functional processes that link parts into the functioning of the whole ecosystem, ecosystem components are frequently defined by their functional roles, especially the aspects that control rates of behavior.

The structural components may, for example, be biota-environment aggregates in a physical sector of the ecosystem, like all parts below ground. Structural components could also be aggregates with common turnover times or rates of matter-energy processing. Ecosystem organic matter stores may be distinguished by turnover times (perhaps controlled by rates of decay) without separating dead organic matter from the soil microbes that feed on it.

Descriptions of ecosystem structure frequently do not consider the distribution of matter or energy among populations of species. Often a middle ground is taken in which biological components are grouped according to a mix of criteria including functional roles, types of bodily form, distributions in time and space, and occasionally coarse distinctions between types of related organisms. For example, in describing the carbon structure of a forest ecosystem, green plants may be distinguished from other organisms that feed on them: animals. The growing green plants may be further divided into trees and non-trees of overstory and understory. The trees may be yet further divided into deciduous and evergreen forms. Adding process to this structure requires input and output rates for organic material and turnover times of these variously defined components. Usually, ideas of structure precede those of function and process. But even in these cases the concept of ecosystem behavior often influences the choice of components.

2.6 Ecosystem As Perspective

A distinction arises between, on the one hand, a population-community approach to ecosystems which focusses upon organisms as structures, and on the other hand a process-functional approach which looks at fluxes and processes[21]. The former emphasizes species populations and interactions between them like competition and predation. The latter emphasizes the transfer and processing of matter and energy. In the population-community approach the physical (abiotic) environment is seen as external to the system of biota and biotic interactions. In the process-functional approach the physical environment is an integral component of the system. In the extreme, this dichotomy emerges as a distinction between community as the system of populations and ecosystem as the system of matter-energy flows through biota and environment. There is nothing to stop a hybrid usage of organisms and process-functional usage, but it may be hard to make them both work at the same time and still keep things straight. The common separation of community and ecosystem ecology in textbooks and classrooms is evidence of this dichotomy. It is not that the population-community conception ignores the physical environment; it is that making the physical environment the explicit context emphasizes a particular type of biotic/abiotic interaction where mass balance and conservation of matter are not so important.

Note, however, that both approaches emphasize interactions. One emphasizes interactions between organisms, the other fluxes of matter and energy. Thus *a process-functional ecosystem* may be identified as a perspective, a particular way of looking at the biota and environment of an area. *Community* is only a different perspective on the ecosystem of "the ecosystem approach".

These perspectives have been called criteria for distinguishing foreground from background, for distinguishing an object from its context[22] (Figure 5). The

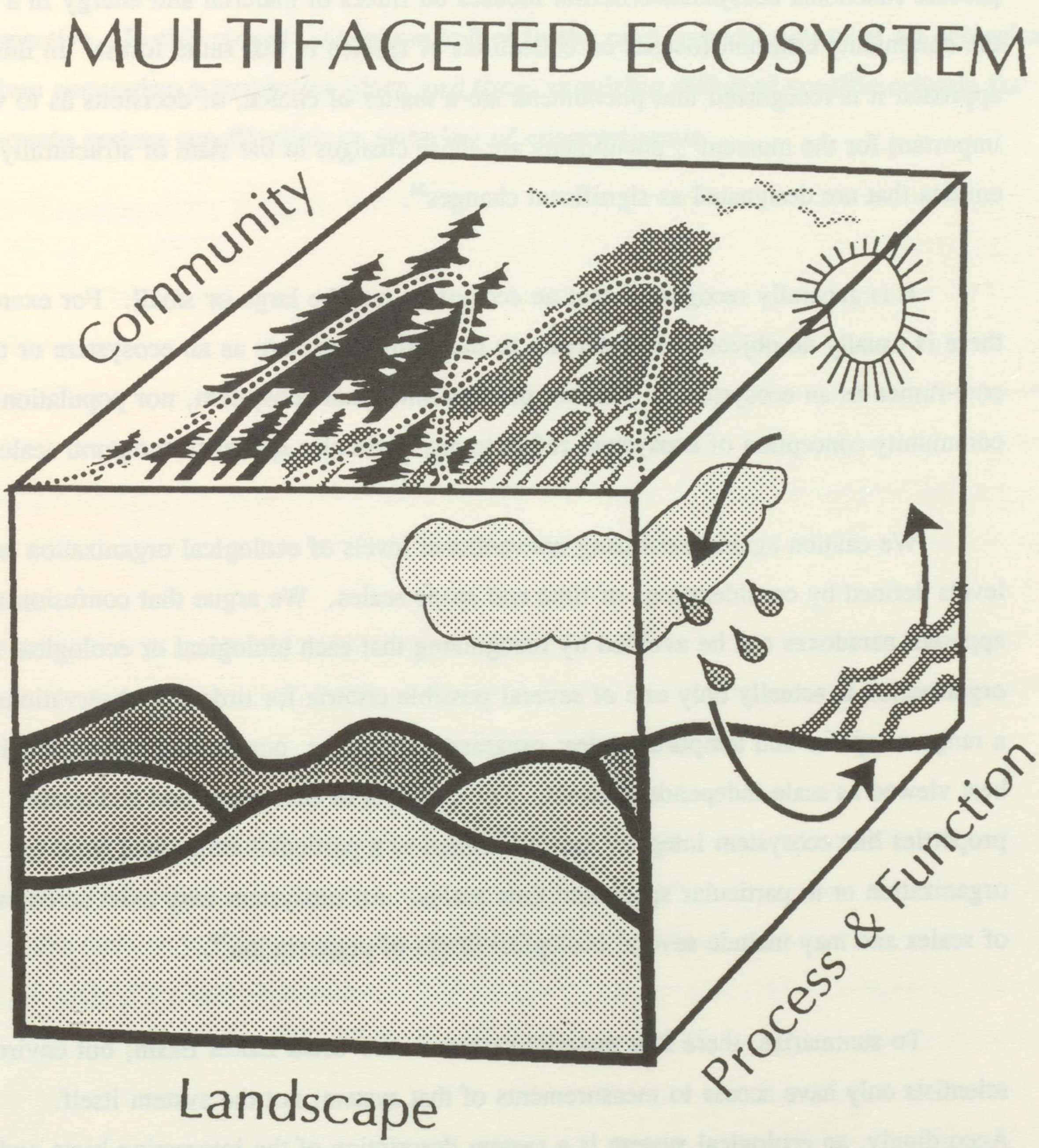


Figure 5. To describe the ecosystem adequately, ecologists must often use different criteria to expose different facets of ecosystem functioning. Here just three major ecological criteria are depicted as alternative ways of observing the system. Under each criterion, a distinctive set of relationships define what is the foreground, the ecosystem, and what is the background, the context of the ecosystem. The landscape is organized around spatial relationships, the community is the relationship between multiple species, while the process-functional ecosystem has its parts bound by flows of material.

process-functional ecosystem criterion focuses on fluxes of material and energy in a forest; the community criterion focuses on collections of species in that same forest. In this general approach it is recognized that phenomena are a matter of choice, of decisions as to what is important for the moment[23]; phenomena are those changes in the state of structurally defined entities that are designated as significant changes[24].

It is generally recognized that an ecosystem may be large or small. For example, there is usually no objection to referring to the entire biosphere as an ecosystem or to the cow-rumen as an ecosystem[25]. Neither process-functional ecosystem, nor population-community conception of ecosystem refers to any particular spatial or temporal scale.

We caution against confusing conventional levels of ecological organization with levels defined by considerations of time and space scales. We argue that confusion and apparent paradoxes can be avoided by recognizing that each biological or ecological level of organization is actually only one of several possible criteria for ordering observations across a range of spatial and temporal scales; organism, landscape, population, or community are best viewed as scale-independent levels. The concepts of ecosystem and ecosystem properties like ecosystem integrity are not limited to a particular ecological level of organization or to particular space and time scales. An ecosystem may exist across a range of scales and may include several biological levels of organization[26].

To summarize, there is a material system in the Great Lakes Basin; but environmental scientists only have access to measurements of that system, not the system itself. Accordingly, an ecological system is a system description of the interacting biota and environment of some place over some time period. A realistic account of any ecosystem in the Great Lakes region must include explicitly human activities like dredging and implementation of fisheries policy. System description may focus upon individuals or populations and their interactions in processes like competition which transfer information among components. On the other hand the system description may emphasize functional components and the transfer of matter-energy. Which type of distinction is used is secondary to the primary concept that the ecosystem is a system. Ecosystem may be used as shorthand for ecological system[27], but it should be remembered that for many the term *ecosystem* invokes a biased view towards a system of matter or energy transfer, or a process-functional perspective. **In this report ecosystem refers to the most general notion of an ecological system occupying a particular place and time, requiring different specific criteria for adequate system specification or ordering of observations.**

3.0 ECOSYSTEM INTEGRITY

3.1 Ecosystem As System

In the Great Lakes Water Quality Agreement, the ecosystem approach is the preferred means of maintaining the integrity of the waters of the Great Lakes Ecosystem. Integrity here generally refers to the soundness or completeness of some thing, the state of being whole and unimpaired. The notion of ecosystem integrity is intuitively appealing and understandable. We wish our ecosystems to be sound, whole, and unimpaired; and we understand, intuitively, what it means for an ecosystem to be in that state.

However, monitoring, managing, quantifying, analyzing, or legislating ecosystem integrity requires a more precisely defined and operationally tractable concept of ecosystem integrity. What then is the state of being whole and unimpaired?

A system description simultaneously involves both structure and process. Description indicates what are the components, how they are connected, and how they operate together. System integrity thus implies the integrity of both system structure and process. It implies maintenance of system components, interactions among them, and the resultant behavior of the whole system. Examples of whole system behavior could be forest development or the processing of energy.

The word "function" might be helpfully distinguished here from mere process. Ecosystem "function" implies not just dynamics but dynamics relative to a proper normative behavior. Since purpose comes from something fitting into the whole, the word "function" pertains more to the dynamics of the healthy functioning whole, as opposed to mere changes of state.

Strictly speaking, loss of any system component or any change in interactions can be viewed as a loss of system integrity. The system is no longer whole; something is missing or displaced. Thus the loss of even a single species or population (a structural component) could be viewed as a loss of ecosystem integrity. However, to a considerable degree, the intuitive concept of ecosystem integrity is biased towards process-focused integrity. That is to say the first conception of ecosystem integrity is usually of the integrity of ecosystem function, a maintenance of the whole system's integrated dynamic. Function is often a consequence of structure, and a change in structure may thus alter function. Obviously, loss of all plants, all primary producers (a structure defined by function), has dire consequences for the functioning of the entire ecosystem.

Some species play a special role in maintaining the system. Loss of such a "keystone"[28] species can influence ecosystem function; invasion by exotic species (an addition of structure) can, in some circumstances, alter ecosystem functioning[29]. However, many systems, including ecological systems, are amazingly resilient to alteration of structure. Whole system functioning may be maintained despite the structural change. Changes in internal system structure may often have little, or very transient, impact on the functioning of the entire system. Some ecosystem components perform their function in parallel, as when two species of grazer both process plant material. When system components are organized in parallel, loss of one or more parts is often compensated by a redirection of flow through remaining parallel components. Parallel structure in ecosystems is related to the idea of functional redundancy or functional equivalence. Loss of one or more parallel parts may produce very little change in whole system function[30]. Primary productivity or nutrient cycling may, for example, remain relatively constant while species composition changes[31] or dominant species are removed[32].

Systems may also possess more active mechanisms of resilience. Feedback loops in interactions among system components may compensate for structural changes in such a way that whole system function is maintained or quickly restored. Systems may thus show adaptation to structural change or even exhibit healing or recuperative powers. These kinds of responses are widespread, and their existence is easily recognized in clearly dynamically balanced systems like organisms. Ecosystems may exhibit similar responses, at least at the level of restoring leaky nutrient retention systems. However, it is easy to overstate analogies to organism health and healing.

3.2 The Dependency On Perspective

A change in structure with little or no change in function might be viewed as an unimportant or insignificant loss of ecosystem integrity. If the focus is strongly on ecosystem function, the change may not be considered a loss of ecosystem integrity at all. A classic example is a change of biodiversity (e.g., species richness) that produces no observable change in ecosystem function (e.g., primary productivity). Is the species loss an insignificant loss of integrity, or is it even appropriate to consider the change as a loss of integrity at all? Is there a loss of integrity if there is no consequence for ecosystem function?

Once again we are faced with the problem of perspective, the criteria for system identification and the ordering of observations. Changes in a system defined by one criterion may have little impact on observations of that same system defined by other criteria.

Consider the case posed by extremely different ecosystem perspectives involving aesthetic or economic criteria. In both of these ecosystem approaches the human observer is an integral part of the system. There is a flow of resource, value, or other currency between human and non-human components. The human is part of system functions in several ways: a) the human role may be passive, only receiving aesthetic value from the rest of the system; b) alternatively, the human role may be active, receiving natural resources from the material system function, an economic and natural resource perspective. Both of these perspectives can yield legitimate system descriptions. Furthermore, they both impart value to system components in a manner different from a third set of considerations, the more traditional scientific perspectives in which the human is not an integral part of the system. Translating ecosystem integrity defined from one perspective to notions of integrity for another can be problematic, but it is something that we need to consider.

Many forested ecosystems, for example, can recover from even extensive disturbance by fire or logging operations. The integrity of the system as a forest may be wholly retained (i.e., it returns to forest and not to grassland or scrub), and species composition may change only slightly. The distribution of biomass between species may be altered for some time, but this is not necessarily a critical facet of chemical and biotic ecosystem function. From another perspective invoking an aesthetic criterion, the visually pleasing quality of the system may be severely damaged for much of the recovery period. The integrity of the system defined by aesthetic "interaction" with the biota has been lost. Even so, it is worth asking if the integrity of the forest as a forest has been compromised.

Consider also that rare species are often assigned the highest value or priority for preservation or use as indicator species. The attention given to rare species arises in part from the observations that rarity may be a consequence of declining populations in response to stress, and rare species may be more at risk. These observations arise from an ecological community perspective. In an independent set of considerations, there is also an aesthetic element. Humans are attracted to and value the rare or unique. Yet, in either the case of stress indicators or aesthetic considerations, rare species are unlikely to have much impact on the large fluxes of ecosystem function, precisely because they are rare. Common species are more likely to be doing the brunt of the work in ecosystem function. Thus, while the persistence of rare or endangered species is a legitimate measure of integrity from a community perspective, the population levels of common species may be more crucial to the ecosystem's functional persistence and integrity. Rare species may thus be more appropriate indicators of a community integrity which is only one facet of the material ecosystem's integrity. On the other hand, some species with small biomass or rare occurrence can sometimes play a crucial role in larger ecosystem function, as when the dogwood shrub pumps nutrients up from the depths of the soil. We must therefore remain always open to alternative conceptions of the ecosystem.

Ecosystem function is often remarkably resilient to the loss of even common species. Witness the limited change in biomass dynamics of southern Appalachian forests following the demise the American chestnut, a formerly common species[33]. One might well ask what changes in North American ecosystems can be attributed to the loss of the once abundant passenger pigeon? Direct measures of functional properties like nutrient export[34] may be more appropriate measures of ecosystem functional integrity, but they in turn may be insensitive measures of the integrity of species composition.

Thus, assessment of ecosystem integrity using the ecosystem approach is strongly dependent upon the perspective from which observations are organized. Definitions and measures of ecosystem integrity from one perspective may complement, contradict, or be largely independent of those from other perspectives. Care must therefore be taken to define explicitly the perspective used in making statements about ecosystem integrity and in making inferences about integrity from other perspectives. A critical component of the ecosystem approach is a flexibility of world view, and a catholic embracing of several criteria.

The most effective posture is achieved by explicitly examining the integrity of alternative, complementarily-described ecosystems. The work of Rapport *et al.*[35] is a good example. They recognize a general ecosystem stress which involves a loss of integrity, from both process-functional ecosystem and community perspectives (e.g., nutrient leaking and loss of biodiversity, respectively). Even so, note that here the perspectives are limited to those of "natural" ecosystems largely exclusive of the human component. We insist that such a view is too narrow to solve critical contemporary problems, and humans must be cast inside the system.

Each type of system description comes from a distinctive perspective. Indicators of ecosystem integrity should include indicators from as many different perspectives as practical, with care taken to include the human creature as a working part of the whole. Those criteria associated with human value judgements, like ethics, economics, or aesthetics, should not be excluded by a prejudice for scientifically defined, or pristine ecosystems (Figure 6). Thus we come full circle; the detour through the professional environmental scientist's view of *ecosystem* returns to include the ethical, cultural, biological, social, and economic human as a critical ecosystem component.

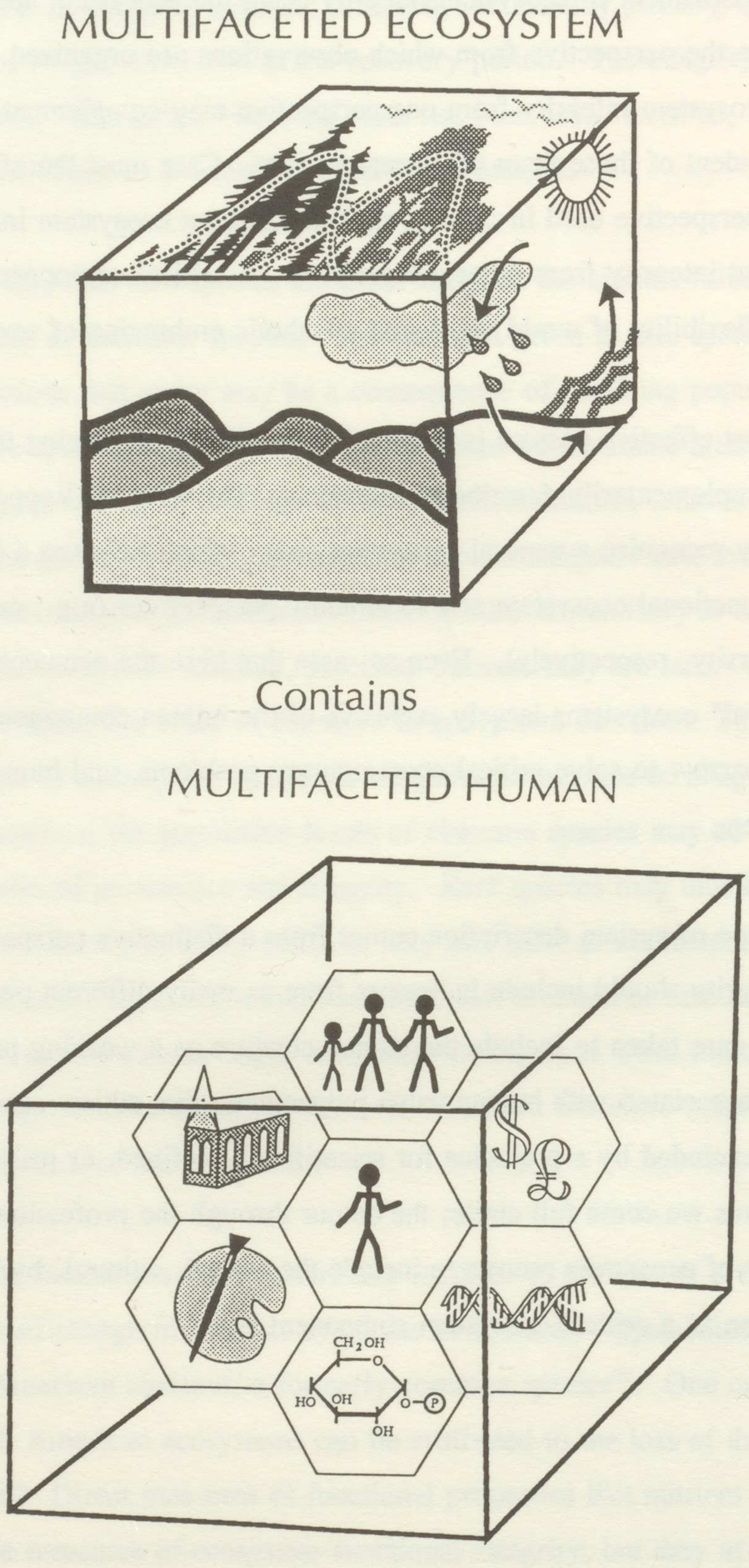


Figure 6. The relationship between humans and the ecosystem takes many forms. A minimum expression must acknowledge a multifaceted ecosystem containing humans showing multiple facets themselves.

4.0 SCALE AND ECOSYSTEM INTEGRITY

The scale of an ecosystem refers to its spatial and temporal dimensions. Scale may simply refer to the size of the system: how large an area does the ecosystem occupy, and how long does a particular configuration of components and interactions persist? Whole-system time constants of behavior may also be used to define the temporal scale of an ecosystem.

Ecosystems which hold material within themselves longer[36], take a longer time to change[37], and return to repeated states less often[38]. Such an ecosystem might be defined as larger scaled or coarser grained. These systems may be more difficult to disturb and may recover more slowly than smaller scaled systems with short mean residence times, high turnover rates, or high natural frequencies[39]. It is worth considering if these larger scaled ecosystems have more or less integrity than fine-scaled ecosystems that are easier to perturb but show resilience and recover rapidly. Large time constants are often positively correlated with spatial extent. Do larger ecosystems thus have more integrity than smaller ones? A definition of ecosystem integrity can be in terms of several system properties: a) resilience, the ability to recover from a large disturbance; b) resistance to disturbance; and c) recovery time. Recognition of lasting integrity in terms of these and several other definitions of stability could lead to productive hypotheses about the relationship between ecosystem integrity and the scale of the ecosystem. These issues deserve research effort on the part of Great Lakes Basin scientists.

Specification of scale is a fundamental part of system definition[40]. The choice of scale at which a system is observed is a primary determinant of the resulting system description. Observations over one hectare and one year will lead to a different system description than observations over thousands of hectares and tens of years. Different extents encompass different components and interactions. Similarly, observations of different grain size resolve different components, interactions, and whole system dynamics. The scale of observation is chosen in the context of the types of ecosystem that are identified at the outset. Once the scale and criteria for observation are chosen, say in casting a Remedial Action Plan (RAP), the ensuing system description is largely determined, unfolding from a process of competent data collection. Consequently, those characteristics of ecosystem integrity which may be observed or inferred are importantly determined by the scale chosen for observation.

The scale of an observation set that is used to define a system and measure ecosystem integrity may be determined by the scale of management units. One might for example wish to monitor or measure the integrity of the Great Smoky Mountains National Park and call it an ecosystem. Observations might then be limited to the spatial extent defined by the park boundary. It may be possible to construct a legitimate system description from observations within those boundaries, but the system description will then be limited to the system existing over scales less than or equal to the extent of the management unit. We can make legitimate inference about that system, but the limited extent of the observation set may not allow valid inference about those ecosystem attributes which apply as attributes of a larger system. This limitation of scale applies even to measures of integrity. The extent of the observation set must be matched to the system attributes of interest. Specifically, the extent of the observation set must be larger than or equal to the extent of the system in question. This is the reason why long term monitoring is important, so that long term ecosystem phenomena can be differentiated from local period fluctuations.

While paying attention to the scale of observation, it is important not to forget that the material system itself requires certain spatial and temporal extents for maintenance of system structure and function. A minimum extent may be required for some process to operate or for some interaction to take place. For example, gap-phase forest dynamics where trees fall and other smaller individuals take over the gap, occur at the spatial and temporal scales of dominant canopy trees[41]. Similarly, the trophic interactions of wolves, moose, and vegetation on Isle Royale are played out over a particular set of space and time scales. Failure to observe the system at these scales can obscure system structure and function and make inferences about ecosystem integrity difficult or impossible. Such failure would likely obscure the appropriate path of material action on the system in implementation of a plan for management, for example a Remedial Action Plan.

Action must therefore be consciously scaled. Restricting the system to an area less than the minimum required for interactions to occur can have an impact on system function and may lead to a loss of ecosystem integrity. Fences may physically impede the flow of interactions in the spatially distributed system and management units (e.g., park boundaries, state lines). Such boundaries may isolate the influence of management practices to scales less than sufficient to maintain system integrity. Witness the impact of agriculture and fencing on African steppe ecosystems. Clearly, the area required to manage wolf populations in the Great Lakes Basin Ecosystem can be much larger than that needed to manage the persistence of an endangered bog plant. A reasonable wolf management unit may well exceed the boundaries of politically defined management units. All this returns to questions of scaled observation. The extent of the observation set required to measure the integrity of the ecosystem supporting North American waterfowl populations is larger than the extent of any single management unit presently in use. The example of innovative management scales and practices required for the management of migratory waterfowl populations can be extended to other ecosystem components (Figure 7).

Ecosystem integrity embodied in the ecosystem approach is a scale-dependent concept. Maintenance of ecosystem integrity implies maintenance of some normal state or norm of operation. Measuring or observing ecosystem integrity, or its loss, thus requires observations over sufficient temporal extent to identify and characterize this normalcy. We are prisoners of perspective; those using the ecosystem approach as a meta-perspective must be aware of that fact. Our concept of normal is empirically bound to the scale with which we observe a system. Long-term observations may reveal slow changes in a system component identified as constant with short-term observations. Similarly observations over a large area can reveal heterogeneity imperceptible from limited local observations. Concepts of normalcy, constancy, variability, and thus ecosystem integrity are only meaningful within bounds set by the scale of observation.

Fire or other disturbance, for example, is often revealed as a normal part of ecosystem operation and seen as necessary to maintenance of ecosystem integrity when the system is viewed from a long-term, large-scale, perspective. Locally and in the near term, fire can thoroughly destroy all integrity of system structure and function, as when changes

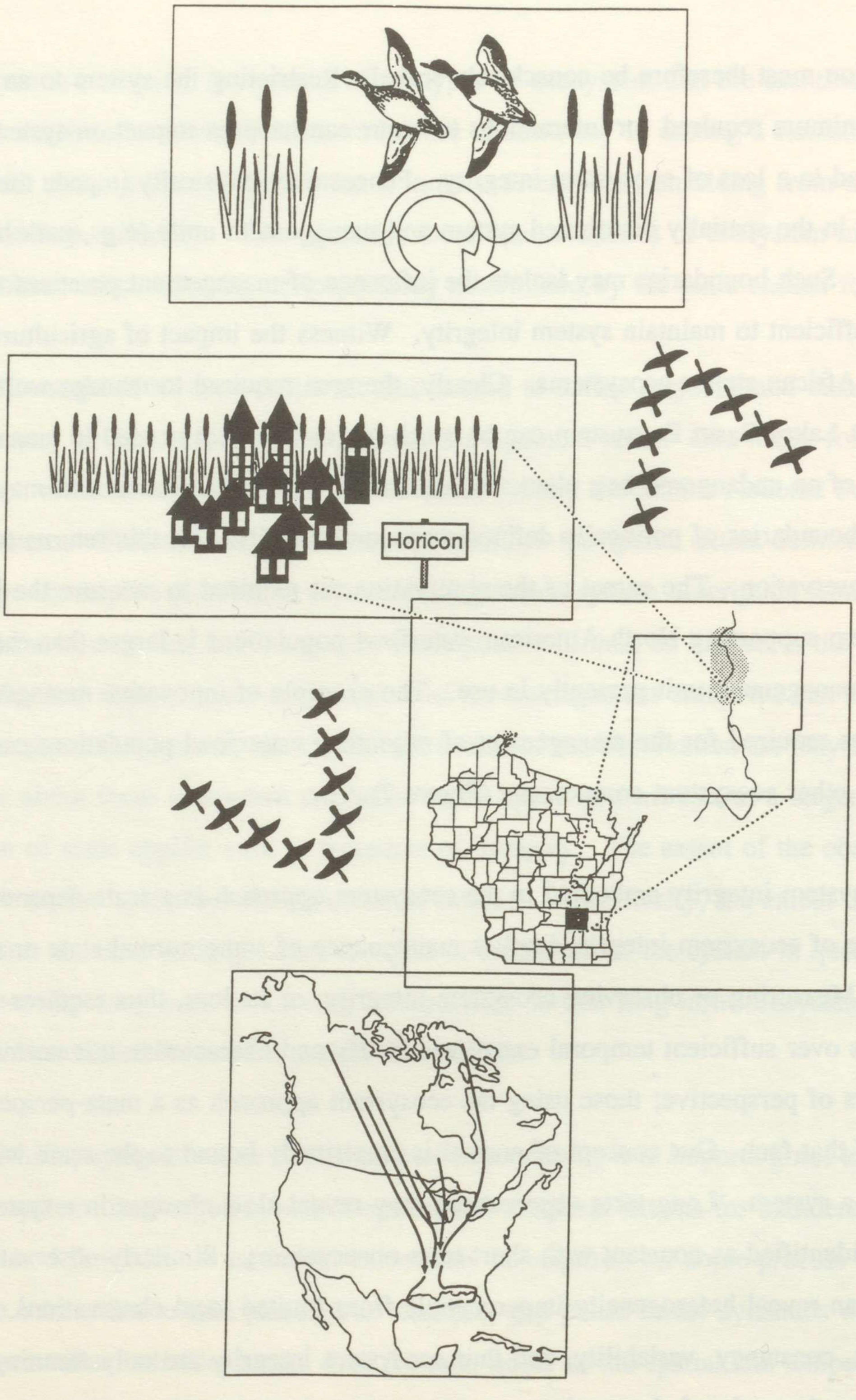


Figure 7. The management of apparently local ecosystems may require dealing with a context that is very much larger. The management of waterfowl in a kettlehole lake ecosystem near Horicon, Wisconsin, requires taking into account considerations at many spatial scales. The spatial extent ranges all the way up to continental flight paths and tropical wintering grounds that need to be viewed as functionally part of, or at least the immediate context of the kettlehole ecosystem. This principle of looking to extremely wide spatial contexts as part of even local ecosystem management should apply to more types of ecosystem management than is presently normal practice.

occur in forest canopy architecture, species composition, and productivity. However, the persistence of the ecosystem, its larger-scale integrity, may in fact depend on the recurrence of these catastrophic smaller-scale losses of integrity[42]. Similarly, observed changes in species composition might be seen as indicating a loss of ecosystem integrity until a larger scale, longer term, perspective reveals that these changes are part of a natural sequence of succession.

Implementation in Areas of Concern

Annex 2 of the Agreement gives, in its General Principles, important guidance concerning the ecosystem approach. In the context of the Agreement's purpose, a key phrase (for those seeking implementation guidance) was crafted in the 1987 Protocol. The key phrase makes it very clear that the ecosystem approach must be **systematic** and that it must be **comprehensive**:

> *Remedial Action Plans and Lakewide Management Plans shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern or in open lake waters. ... The Parties, in cooperation with State and Provincial Governments, shall ensure that the public is consulted in all actions undertaken pursuant to this Annex.*

In Appendix I we include a list of characteristics of a systematic approach to problem solving. Our source, Rowen[43], talks of a systematic approach to systems analysis, but his characterization applies to all problem-solving, including the systematically applied remedy to Areas of Concern using the ecosystem approach. A systematic implementation of the ecosystem approach ensures that no important part of the conceptualization is overlooked. A systematic approach is in essence methodological. It pertains to the activities of and categories erected by the implementers of the approach.

By contrast, comprehensive aspects of the ecosystem approach deal not so much with the conception as they deal with the material side of the ecological system. A suitably systematic approach would be substantially weakened if it did not deal with a sufficiently inclusive material system. The ecosystem approach needs to be comprehensive in both space and time. In space it must include pertinent far flung influences. In time it must include a long enough record to put surprising change in a context. Is the warmer climate of the 1980's a new situation, or is it one part of a regular cycle that will soon reverse? A comprehensive approach requires that we at least know some baselines concerning the old states of integrity.

A systematic approach has the characteristics of good, orderly systems analysis. A comprehensive approach must cover all the significant kinds of interactions present in the system although an explicit accounting of all the material interactions is impossible. It must address a defined set of consciously chosen purposes, not just a heap. The same caveats for the ecologist doing ecosystem science apply to the stakeholder seeking social and ecological accommodations in the Basin.

The Council of Great Lakes Research Managers ... has adopted an ecosystem perspective toward Great Lakes Research. ... The ecosystem approach is such a radical departure from the traditional scientific mind-set that there are few, if any, management tools to support the integration of interdisciplinary science and policy considerations and the setting of research priorities within an ecosystem framework. Without a procedure and a framework for considering policy-relevance and system-wide impacts, the ecosystem approach becomes, at best, a well-intentioned but unfocused assessment criterion, and at worst, a shroud for traditional research practices that continue under the guise of ecosystem relevance.

The solution then is to provide the research managers with a framework for assessing the relative merit of research issues that (1) reflects the interconnectedness of issues, attributes and indicators in the Great Lakes ecosystem, and (2) indicate the policy relevance of the research being considered. The <u>*framework*</u> *would serve as a mechanism for synthesizing current knowledge about the ecosystem, portraying areas of knowledge as well as areas of ignorance. ... Ideally, the framework would embed human activities in natural systems (e.g. the Ecosphere) at various time and spatial scales.*

Biennial Report Committee, Council of Great Lakes Research Managers, <u>draft Council Biennial Report</u>, August 1992

5.0 CONCLUSION

Much as environmental scientists must be flexible in their approaches to the ecosystem, stakeholders in the more widely defined ecosystem of the ecosystem approach must also be flexible. The ecosystem approach insists on a richness of definition of the ecosystem so that large issues facing the Great Lakes Basin Ecosystem can be addressed.

Because problems in the Basin are so multifaceted and are always changing, the process we use to press upon them must be capable of change as new problems arise. The emphasis on flexibility of definition here is important. A problem that is adequately considered under one definition of the system often gives way to a new set of problems that demand new definitions of the ecosystem. Not only may the important features of the system change, but so too may the scale at which we are forced to address them. For example, success in controlling point source loading has only exposed pollution of a different sort, agricultural runoff. As stakeholders we should expect problems to shift underneath us as a rule. Accordingly the ecosystem approach must be prepared to define the ecosystem operationally, and be prepared to change type and scale of ecosystem as new issues demand attention.

Note that the recommendation to be flexible in typing and bounding the system is not an invitation to be vague. Problems can be solved only when our definitions give us a firm handle. Much as scientists ask specific questions that type and scale the system, the ecosystem approach recommends clear casting of issues so that stakeholders can buy in and pull together. In fact, conflict resolution amongst stakeholders is usually achieved precisely by finding a definition of the problem so that everyone wins through the remedial action. With the system appropriately defined, the problem often seems to solve itself. The different facets of the human in the system must find an accommodation: for example, the biological human avoids chemical insult, while the economic human can drive the system to a prosperous condition, wherein the social human with its lust for life of our own and other species is satisfied. Large as problems may be, the only reasonable hope is to find answers to specific questions. The challenge is to find the important questions that can serve all members of the ecosystem. As managers and stakeholders we need firm definitions that come through a process of searching that is expansive, creative, and humane.

There is no one-time solution to the problems in the Great Lakes Basin Ecosystem. The ecosystem approach will not lead us to action that will do the single best thing. Rather the ecosystem approach is a process that keeps identifying problems of various sorts and puts pressure on them so as to improve the situation. Gradually things will be better, which is all the success we as a society can reasonably expect. If society aims to do it right once for all, it will fail and then give up the whole enterprise.

The people of the Basin fool themselves if they think that all that is needed is to deal with Areas of Concern in the Basin are Remedial Action Plans (RAP) that when implemented will put things to right. A RAP is a first step which must be followed by more steps, beyond RAP implementation. Realistically society cannot even hope to get the RAPs fully implemented as a single exercise. Even if it could, the dimensions and complexity of human impact will necessarily leave something unaddressed even by the best, feasible, remedial action planning activity. It is probably sensible to assume that we are not dealing with the best plans and action. It is better to settle for desirable and feasible action applied and recast time and again.

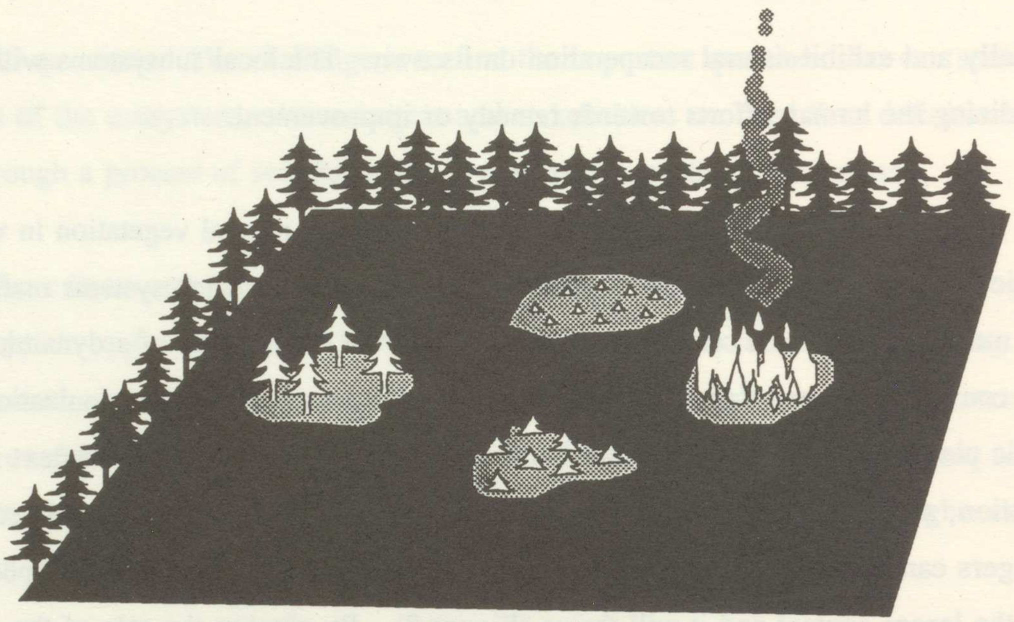
The breadth of vision recommended by the ecosystem approach tends to lead to a contextual approach to problem-solving. A compulsive attempt to control all the little bits of the system only leads to wasted effort in overspecifying the details of the remedy. Rather than malfunction of a system part, often a problem can be profitably seen as a missing or inadequate context. If the stakeholders can identify how the ecosystem with humans within it is failing to service the local subsystems, then society can subsidize the local system in a conscious fashion in the way that a healthy context would have done if it were there. If we can do that effectively, then the local system will work as if it were set in a healthy, fully functioning, contextual ecosystem. At that point many details will solve themselves. The local system will behave as if it has forgotten that it is orphaned and will start to function normally and exhibit natural recuperation on its own. The local subsystems will then be subsidizing the human efforts towards remedy or improvement.

Perhaps human activity has removed the matrix of natural vegetation in which a mosaic of fire or some other disturbance regularly occurs. In such systems many species need mosaic patches at a certain stage of recovery. In the absence of a dynamic patchwork for a context, local populations will go extinct with no compensatory colonization of another mosaic piece coming into the condition of prime habitat. Restoring the context is often not an option, so the managers will have to do the job of context themselves. If ecological managers can keep engineering patches of prime habitat, then the respective species will not miss the larger context and it will thrive (Figure 8). By playing the role of the context we take on a job that we must keep doing but is never done.

The ecosystem approach emphasizes breadth of vision. It demands a critical flexibility of thought and action. It insists that we be self conscious. The ecosystem approach embodies an ethic that asks: do we as individuals behave responsibly to those around us; are we responsible members of society; and are we worthy members of a species that plays a proper role in the biosphere? If we can answer affirmatively on all those counts, the Great Lakes Basin Ecosystem and the world will become a better place.

[I]n a participative, technetronic democracy where success depends on getting everyone into the act of planning for the future, there seems to be little basis for hope in the outcome unless there is a common language and a common orientation to the problem.

-- *Jere W. Clark, "The General Ecology of Knowledge in Curriculums of the Future" in* *__The Relevance Of General Systems Theory: Papers Presented to Ludwig von Bertalanffy on His Seventieth Birthday__*, *edited by Ervin Laslo*



Mosaic of Patches in a Contextual Matrix

Humans Subsidize Local Unit

Figure 8. Management often takes the form of human activity subsidizing the local management unit to perform services that would have been offered by a context which prior human activity has removed. Managing from the context allows the forester, wildlife manager, city manager, or stakeholder group to integrate complicated processes inside the local system. The effect of this is to reduce management action to the facilitation of input and output to and from the managed system. If this role is performed adequately, the managed system behaves as it would were it still set in its full primitive environment. The local managed system functions internally to subsidize the management effort.

While written at a level in between that of the specialist environmental scientist and the concerned lay public, the present report has attempted to lay out something of a common set of concerns and caveats. Part of the ecosystem approach will be further translation of the unified ideas presented here into terms immediately accessible to non-specialist stakeholders. A learning component to the ecosystem approach is crucial.

> *Science should seek that which is robust to transformation, that which persists when viewed on several criteria. ... Players in more than one ecological structure occur in more than [one] ecological cycle. It is those players in more than one game that embody the places where cyclical processes that pertain to several criteria come together. Those structures are the places where the various cycles of nature kiss. Those will be the instruments for generality that are central to the unifying scheme that might pull ecology into a cohesive whole.*
>
> *-- Timothy F.H. Allen and Thomas W. Hoekstra,*
> *Toward a Unified Ecology (1992)*

6.0 RECOMMENDATIONS

In addressing the ecosystem approach to achieving better understanding of the Great Lakes Basin Ecosystem, the authors have striven to devise an overview. We have kept in mind the caution given by the Great Lakes Research Advisory Board (in its report, The Ecosystem Approach, of July 1978) that "The Parties and the Commission should beware of persons and organizations who may seize upon the word *ecosystem*, using it to serve narrower interests to the detriment of implementing the ecosystem approach." Our report -- despite its insistence on appropriate specificity in system definition -- is of necessity a general survey. Rather than serve narrow interests, it points up ways of looking outward to find common interests.

Our principal recommendation for the ecosystem approach is: Be flexible in typing and bounding the ecosystem. That recommendation is not encouragement to be lax in raising important questions concerning the ecosystem of interest. As we stressed earlier, the specificity of a scientific question relates to its explicit nature rather than to its narrowness. In the ecosystem approach, we, the stakeholders, should craft appropriately expansive questions so that the ecosystem of interest becomes defined to be particularly inclusive. The approach is characterized by working between and among institutions and between issues to create meta-issues of importance.

We recommend, therefore, that the Great Lakes Science Advisory Board organize its activities and its task forces so as to implement the Ecosystem Approach for developing advice in dealing with matters of integrity of the Great Lakes Basin Ecosystem (GLBE).

General Recommendations

The method developed in this report suggests a treatment of ecosystems, cognizant of different scales of operation involving many types. Multiple scales of perception and conception combined with a recognition of a richness of types of ecosystem considerations is a requirement for adequate ecosystem management. The authors urge that in making its recommendations to the Parties, the International Joint Commission couch its advice in terms are consistent with a multifaceted and multiple scaled approach to the ecosystem. This would apply to the following specific areas of policy making and implementation.

(1) Policy for ecosystem management should continue to be developed in a way that encourages systematic and comprehensive information gathering, study, and action. Piecemeal approaches are counter to an ecosystem approach.

(2) Coordination between agencies and jurisdictions needs to be performed in a way that recognizes ecosystem complexity and integration.

(3) From our conception of the ecosystem, it follows that research activities are likely to appear superficially duplicated; usually such will not be the case. A given facet of the ecosystem is likely to need separate consideration for each context in which it arises. Tolerance for what might appear as redundancy of effort is going to be a requirement for casting the ecosystem in terms that are rich enough to lead to significant remedy and maintenance.

(4) The multiple-scaled conception of the ecosystem requires explicit treatment of long term considerations beyond immediate symptoms and action with regard to those symptoms. Accordingly, agencies and administrative structure must have long term stability of high-ranking ecomanagement personnel. They need to have significant cultural memory, a commitment to long term monitoring, and research activity with a long term vision.

(5) The converse of long term considerations is the need to be flexible in addressing the ecosystem. While large scale administrative structure is important for continuity, richness recognized in the ecosystem requires agencies to be able to liaise informally as local facets of the ecosystem demand. Informal liaison is essential for dealing with the short term, high frequency aspects of ecosystem management. In the spirit of general recommendations 4 and 5, leaders from multiple agencies with jurisdiction across the Basin have been meeting regularly and the Parties should be urged to pay attention to those deliberations[44].

<u>Recommendations for specific action</u>

Beyond general recommendations as to the spirit in which advice might be offered to the Parties, we have some recommendations for specific action regarding implementation of the Great Lakes Water Quality Agreement.

(1) The Great Lakes Science Advisory Board (GLSAB) should commit to publishing (in the 1993-1995 biennium) an edited and illustrated version of this overview report, <u>The Ecosystem Approach: theory and ecosystem integrity</u>. The GLSAB report should be a special report of the GLSAB to the International Joint Commission. It should also be accompanied by an <u>Annotated Bibliography</u>.

(2) The Council of Great Lakes Research Managers' issue-driven ecosystem framework for decision making is clearly in the spirit of the ecosystem approach as described in this document. As a complement to that, the new task force structure of the Science Advisory Board is also a move towards implementing an ecosystem approach to Commission activities. While expansive in their scope, the issue-driven framework and the task forces are not in any way vague as to their goals and protocols. In this same spirit, we recommend that the Science Advisory Board ask some specific but expansive questions that would lead to the creation of further task forces or study groups. To indicate the scope that the authors have in mind, an example question might be: "How does organochlorine stress in the ecosystem compromise the capacity of the ecosystem to accommodate to climate change?" Note that the question looks outward from a basin-wide

scope and that it requires the combined expertise of toxicologists and climatologists. Even so, the question is most explicit.

(3) In an ecosystem approach, the concept of human-in-the-system is crucial. Furthermore, the human is recognized as multifaceted. A suitably rich and multifaceted human component can only be inserted into Commission activities by the active inclusion of a diverse set of stakeholders in planning. The learning component of the ecosystem approach is much more than merely educating the public. Scientists, policy-makers, and managers must all be informed by an open dialogue with an array of stakeholders. There are various protocols for achieving such an exchange and broadly based involvement. We are aware of none that is more appropriate than that of Peter Checkland (1981). We recommend that Checkland's protocol be employed in the execution of both the general and specific recommendations above. There follows an account of Checkland's seven-stage methodology outlined in his 1981 book, Systems Thinking, Systems Practice.

The Checkland methodology places an emphasis on ""the importance of moving quickly and lightly through all the methodological stages, several times if necessary, in order to leap the gap between "what is" and "what might be.""

Checkland's Methodology applied to The Ecosystem Approach

The ecosystem approach, like Checkland's methodology, acknowledges that the choice of the ecosystem is, itself, part of the problem. In addressing "soft" problem situations such as those involving human/environment relations in the Basin, we found that no systems hierarchy relevant to the problem can be taken as a given. As Checkland put it, "Problem definition ... depended upon the particular view adopted and ... it seemed necessary to *make that viewpoint explicit* and work out the systemic consequences of adopting it."

The Ecological Committee has found no more appropriate methodology than Checkland's for making operational the ecosystem approach. In briefest outline, as he describes it, that methodology lacks "the precision of a technique but will be a firmer guide to action than a philosophy."

Checkland continues,

[I]t should be capable of being *used* in actual problem situations; it should be *not vague* in the sense that it should provide a greater spur to action than a general everyday philosophy; it should be *not precise*, like a technique, but should allow insights which precision might exclude; ...

The methodology contains two kinds of activity (Figure 9). Stages 1, 2, 5, 6, and 7 are 'real-world' activities necessarily involving people in the problem situation; stages 3, 4, ... are 'systems thinking' activities which may or may not involve those in the problem situation, depending upon the individual circumstances of the study. In general, the language of the former stages will be whatever is the normal language of the problem situation, that of 3, 4, ... will be the language of systems, for it is in these stages that real-world complexity is unravelled and understood as a result of translation into the ... meta-language of systems.

Stages 1 and 2 are an 'expression' phase during which an attempt is made to build up the richest possible picture, not of 'the problem' but of the *situation* [R. Ackoff's "mess"] in which there is perceived to be a problem. The most useful guideline here ... is assembling a picture without, as far as possible, imposing a particular structure on [components]. ...

Stage 3 then involves naming some systems which look as though they might be relevant to the putative problem and preparing concise definitions of what these systems *are* -- as opposed to what they *do*. The object is to get a carefully phrased explicit statement of the nature of some systems which will subsequently be seen to be relevant to improving the problem situation. This cannot be guaranteed, of course, but the formulation can always be modified in later iterations as understanding deepens. These definitions in stage 3 are termed 'root definitions', which is intended to indicate that they encapsulate the fundamental nature of the systems chosen. ... (Checkland 162-164 passim)

Allen and Hoekstra (1992) lay out a summary of Checkland's process of finding root definitions.

Explicitly, the root definitions can be remembered by the acronym CATWOE. "C" is the client of the system and analysis; for whom does the system work? Sometimes the "client" is the person for whom the system does not work, namely the victim. "A" refers to the actors in the system. These could be the client or victim as well, but often the actors are separate entities. In the scheme that we have used to this point, these are the critical structures. In human social problems these are likely to be actual people, whose scale depends on their scope of influence. However, the

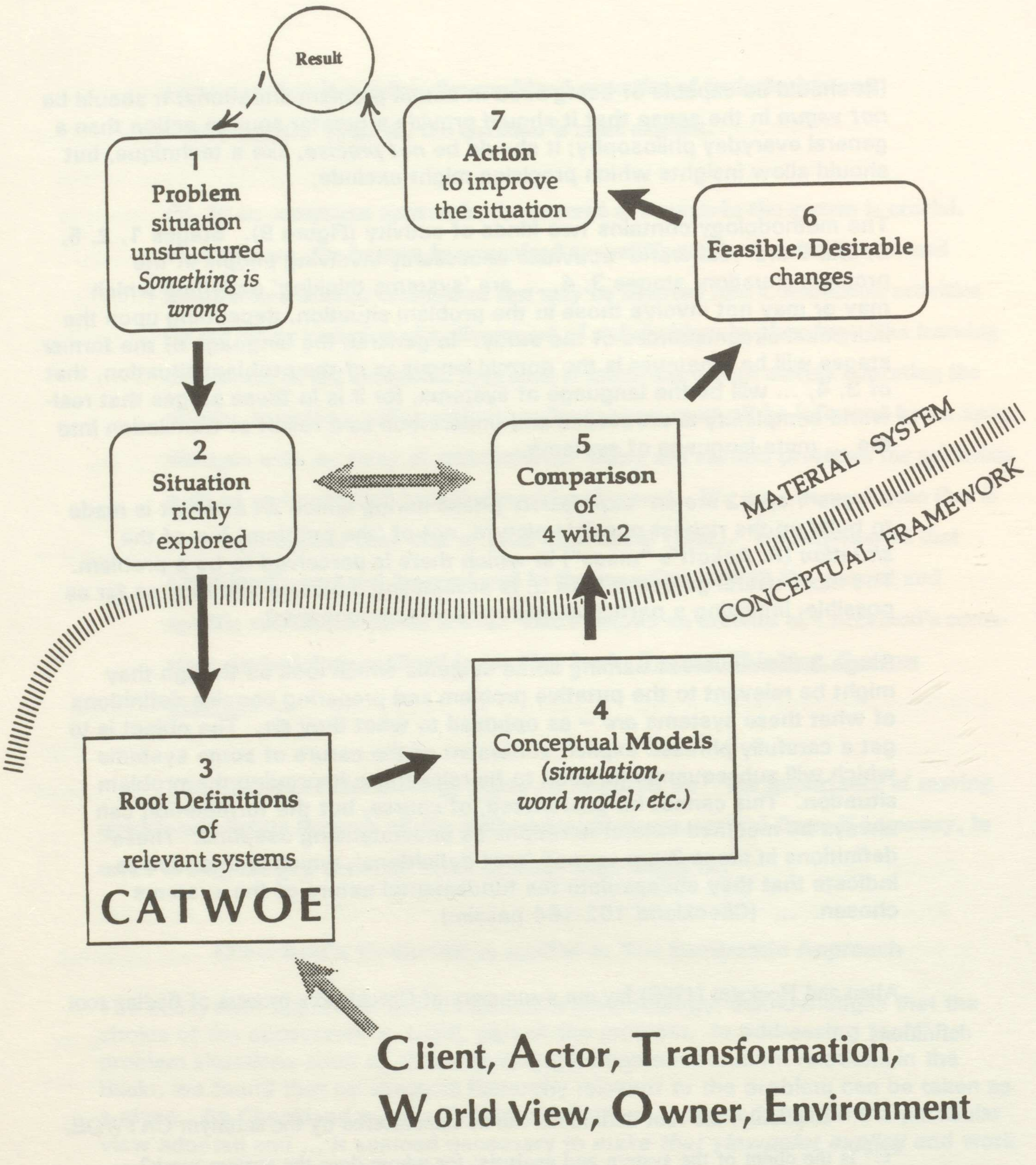


Figure 9. The entire process of Peter Checkland's Soft Systems Methodology redrawn from Checkland (1981). The seven steps work either with the "systems thinking" aspects of the problem or the "real world," in Checkland's terminology. We prefer to call this division the conceptual and the material system respectively. Note the acronym CATWOE, for root definitions in step 3. By identifying the Client, Actor, Transformation, World view, Owner, and Environment, the problem solving stakeholders scale and type the situation so as to avoid ambiguity and unnecessary dissention.

actor could be a forest in an ecological system. Implicitly, the actors set the scale. All this is clear enough with hindsight, but in less obvious situations it is important to be open to new levels of analysis and explicit as to the level in use. Choosing an actor achieves that end.

"T" are the transformations or underlying processes. What does the system do? What are the critical changes? These critical transformations are generally performed by the actors. "W" identifies the implicit world view invoked when the system is viewed in this particular manner.

> "T" identifies.... the naked, measured changes of state. In a larger view, "T" pertains to the subjectively identified significant differences, our "phenomena." "W" isolates the subjectivity embedded in the choice of the phenomenon from the transformation that is implied in the critical change that embodies the phenomenon.... [T]he phenomenon fixes the type of entity that is either found as a context, or as a mechanism. These would be the upper-level actors, whose identity defines either a reason or role when one moves upscale, or an explanation and mechanism as one moves downscale. Thus "A," "T," and "W" together identify whether it is a community study, an ecosystem study, or whatever else, and the scale of the investigation.

"O" refers to the owners of the system, who can pull the plug on the whole thing. Like the actors, the owners could be the client or victim of the system, but usually the owner is someone else. The scaling issues of grain and extent emerge here. With power to terminate the system, the owner defines the extent aspects of the scaling of the study. By contrast, the actors will usually define the coarsest grain that can be involved in scaling the system because they have to be discernible at the level of resolution associated with the specification of the system.

> ....[I]t is helpful to know the ultimate limits to the functioning of an ecological system, and the concept of owner might be of service there. For example, the fact that ice ages have pulled the plug on plant community associations in the past

indicates the extent to which communities start as ad hoc entities. As an owner, global climatic shift puts limits on the evolved accommodation that is embodied in community structure. In managed or restored ecological systems, the owner can apply in very literal terms.

Last, "E" identifies the environment, that is, what the system takes as given. Anything longer term and slower moving than the whole system is a context with which the system has to live. By default, the environment defines the scale of the system extent by being everything that matters which is too large to be differentiated.

It is important to realize that the several different sets of root definitions are not only possible, but desirable. The actors in one set of definitions will be different from those in another. That presents no problem, but it is mandatory that the actors in question only act in the model for which they have been identified, and are not mistaken for actors performing at some other scale on a different set of assumptions. In fact, that error is exactly the sort of confusion which arises if the formal scheme recommended here is not followed. Mistakes are easy to make if there is not a formal framework to keep track of all the relationships. That error of sliding the scale or change of worldview is a favorite device for vested interests to confuse the issue when they know that their own position is inconsistent. Lawyers representing either the company in an environmental litigation, or an environmental action group bringing suit, can confuse an issue in this way, if they are in danger of losing (Allen and Hoekstra pp. 311-314 Passim).

Returning to Checkland's outline of his seven step procedure:

> **Given this definition, or better, these definitions, ... stage 4 consists of making conceptual models of the human activity systems named and defined in the root definitions.**
>
> **Model building is fed by stages 4a and 4b: 4a is the use of a general model of any human activity system which can be used to check that the models built are not fundamentally deficient [pursuant to the Great Lakes Water Quality Agreement, they would have to embody good systems analysis and be comprehensive]; 4b consists of modifying or transforming the model, if**

desired, into any other form [e.g., a computerized simulation model interactive with scenario-builders] which may be considered suitable in a particular problem. ...

Whether or not this kind of transformation takes place, the models from stage 4 are then, in stage 5, 'brought into the real world' and set [e.g., via a computer-based geographic information system] against the perceptions of what exists there. The purpose of this 'comparison' is to generate a debate with concerned people in the problem situation which, in stage 6, will define possible changes which simultaneously meet two criteria: that they are arguably *desirable* and at the same time *feasible* given prevailing attitudes and power structures, and having regard to the history of the situation under examination.

Stage 7 then involves taking action based on stage 6 to improve the problem situation. This in fact defines 'a new problem' and it too may now be tackled with the help of the methodology [Checkland, *op. cit.* p 164 passim].

In the 1978 book, Adaptive Environmental Assessment and Management, Holling *et al.* noted that good policy design relies upon concepts and methodologies for the organized treatment of the unknown, the missing, and the intentionally "left out". In representative governments, any strategies for ecomanagement must make arrangements to keep the support of stakeholders -- particularly when some values dear to those stakeholders are missing in particular iterations of planning efforts.

"Tiering" [40 CFR 1508.28] is such a strategic element in the NEPA process in the U.S.A. Tiering is the coverage of general matters in broader plans such as national program or policy statements with subsequent narrower statements (such as regional or basinwide program statements or ultimately site-specific statements), concentrating solely on the issues specific to the statement subsequently prepared. Tiering is analogous to "scaling". It can be used, systematically, to deal (at some tier) with issues of a particular scale. Nested hierarchies of plans can be devised to ensure (spatially and temporally) that stakeholder issues at all levels are dealt with at the most appropriate level.

The authors believe that the ecosystem approach has dimensions sufficient to any strategic challenge posed by threats to the integrity of the GLBE and to the biosphere and ecosphere, for that matter. Right now, one of those strategic challenges is to find ways of ensuring that affected entities are enfranchised by particular ecomanagement plans, programs, and projects.

A strength of the ecosystem approach is that it leads to a contextual approach to problem-solving. Applied in a methodology such as that developed by Checkland, it can come close to ensuring that an observation set used to define the GLBE and to measure ecosystem integrity will not be capricious in the organized treatment of the unknown, the missing, and the intentionally "left out".

Good science, the kind of science that the Great Lakes Science Advisory Board should encourage, is science that leaves a trail -- an open trace to what led to the

Board's advice. Appropriately applied, the ecosystem approach is good science leading to fitting and ecologically well-informed policy.

In this iteration of The Ecosystem Approach, the final recommendation of the Ecological Committee is that the Great Lakes Science Advisory Board -- when it addresses the Great Lakes Basin Ecosystem in offering advice -- make clear at the outset what process or processes of system definition and system delimitation it is using.

Scientific truth only applies within certain defined regimes. Specifying the context in addressing an ecosystem makes those definitions explicit. It makes them amenable to testing. Establishment of a baseline also encourages further learning and allows some measurement of changes in an ecosystem and in its perceivers.

At any scale, in any iteration, the ecosystem approach begins (and determines its end) by an explicit specifying of context for the subject ecosystem.

> ***"Knowledge opens all experience to wonderment and appreciation. Limits do not confine, but are available to be known within the vital immediacy of knowledge. Knowing is not something to be attained in the future in an unfolding rhythm of waiting or preserving; it is available now, within what we know and do not know. Acknowledging what we do not know, we can resolve to free ourselves of the limits that narrow our vision and undermine our well-being."***
>
> ***--Tarthang Tulku, Love of Knowledge (1987)***

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Appendix I

The International Council of Scientific Unions' Scientific Committee on Problems of the Environment (SCOPE) noted that good systems analysis has the following characteristics:

(i) The approach to the problem should indicate that the analyst understands the essential nature of the practical problems.

(ii) The analysis uses methods which fit the character of the problem and the nature of the available data, while treating all data skeptically.

(iii) Systems analysis defines, explores, and reformulates objectives, while recognizing that there may be several objectives capable of being arranged in a hierarchy.

(iv) Good systems analysis uses criteria sensitively and with caution, giving weight to qualitative as well as quantitative factors.

(v) Effective analysis emphasizes design and creation of alternative solutions and options, and avoids concentration on too narrow a set of options.

(vi) Modelling within systems analysis should handle uncertainty and stochastic variables explicitly.

(vii) It is important to use simple models to simulate the essential aspects of the problem, and to avoid large and complex models that attempt to mimic reality while concealing the basic structure of the problem and the uncertainties of the estimation of model parameters.

(viii) The results should display honesty in the labelling of assumptions, values, uncertainties, hypotheses, and conjectures.

(ix) The analysis and its results should also show that an effort has been made to understand the practical problems and constraints of management and administration, especially if the analysis suggests a radical reformulation of the problem.

(x) The solutions should take into account the organizational factors that affect the alternatives generated and influence the decisions.

(xi) Good systems analysis makes as certain as possible that the suggested alternatives are feasible.

(xii) The analysis should consider the difficulties of the implementation of solutions and the costs of achieving them.

(xiii) The analysis should recognize that an approximate solution before any decision has to be made is better than an exact solution long after the decision has been made.

(xiv) The whole procedure of systems analysis should exhibit awareness of partial analysis (constrained by knowledge, by reductionistic language, and by abstracting from the unitional ecosphere), and the limits of analysis generally.

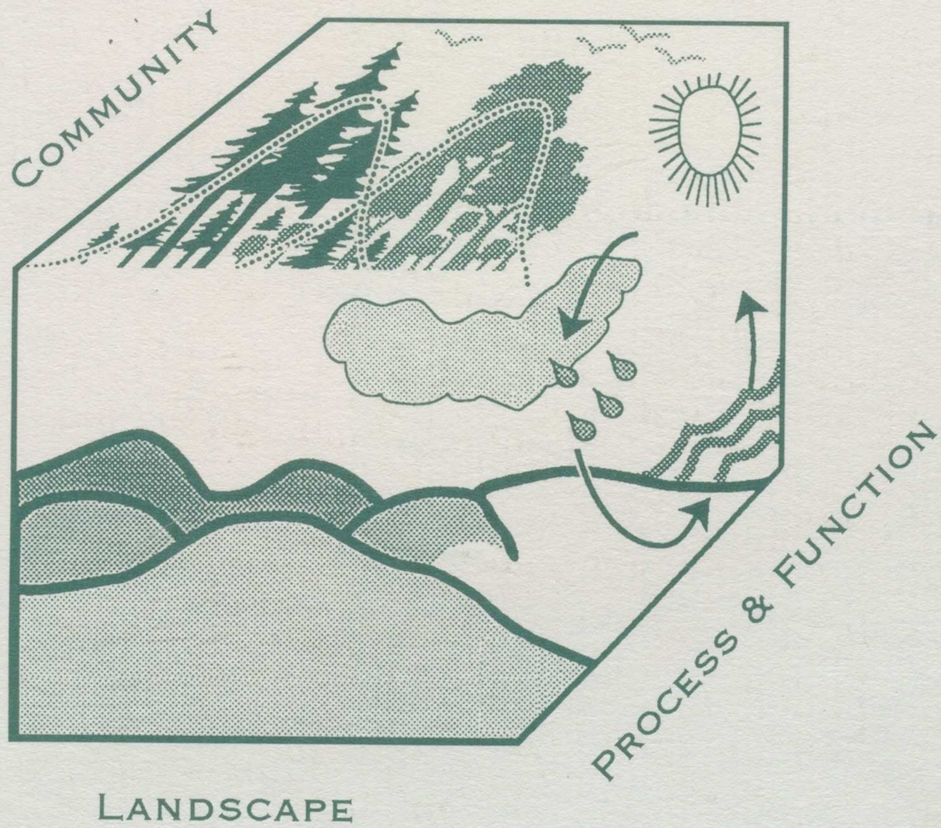
(xv) The whole process of systems analysis should demonstrate understanding. The task is not merely to indicate the "best" solution, but also to develop a range of alternatives.

This list was compiled from two sources:

from Rowen, H.S. (1976). "Policy Analysis as Heuristic Aid: the design of means, ends and institutions" in When Values Conflict, published by the American Academy of Arts and Sciences; and

from experience gained in the International Institute for Applied Systems Analysis, a nongovernmental research institution located in Laxenburg, Austria.

Ecosystem conceptions of many types
can appear in the foreground; and
revealing where their common facets kiss,



These ecosystems can serve
to unify our awareness
and our understanding.