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Guest Editorial

Considering theoretical and practical needs of ecology[1]

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In this plenary lecture I want to focus on a contradiction. On one hand, the science of ecology, as an academic discipline, seems enormously healthy. The number of students seeking training in ecology rises, the number of research manuscripts submitted to journals of all kinds increases and there appears to be greater need for the information and theory of the science. If size or activity is a measure of health, then ecology, by these criteria, is healthy. Indeed, ecological science seems to be sharing in the overall economic well-being of humans generally. On the average, humans live longer, are healthier, have better diets and are freer of the capricious impacts of environment and society than ever before.

On the other hand, it is generally true that the condition of the environment is poor and it is deteriorating annually. This is true in at least two broad ways. First, the area of natural habitat and the number of species living in that habitat are being reduced and, secondly, the functioning of the environment at global to local scales is changing. It is abundantly clear that the ultimate cause of these phenomena is continually increasing human demand upon the environment, associated with the recognized improved human well-being and the increased numbers of humans.

The contradiction is that ecological work has greatly expanded and is at an all-time high at the same moment that the conditions of the environment are worsening and becoming a true crisis. The stock ecological explanation for this contradiction is that decision makers and the public do not understand and apply the data and theory of ecology. If the public were environmentally literate, it is

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suggested, they would support policies and programs that improve the environment and create the conditions for sustainability.

An alternative explanation of the contradiction is that scientific ecology has little or nothing to do with the conditions of the environment. As an ecologist I find this suggestion to be difficult to accept, although there are non-ecologists who claim that ecology is irrelevant in this arena of public policy.

Logical analysis of the situation suggests that problems may exist within ecology, in public administration and policy or in both. I am qualified to say something about ecological science so I will restrict my remarks to the science, without implying that ecology is solely or even largely responsible for the contradiction.

In this situation it is helpful to have a viewpoint in time. I recall almost 50 years ago being deeply concerned about the state of the environment, which helped me to decide on a career in conservation and ecology. The analyses, interpretations, conclusions and proposals for action then were, in general, the same as those of today. What is different, is that over these 50 years the calls of concern have become more strident as the environmental conditions of the Earth deteriorate and greater and greater amounts of money have been spent on environmental problem-solving. The contradiction I have described is of long standing and has not been resolved.

In my opinion, a factor underlying this dilemma is that the theory of ecology is out of phase with the taste or style of the time. Ecologists, as natural scientists, have tended to approach nature from a mechanical, materialist perspective and have treated humans as separate from the natural environment. This was an acceptable scientific method in the earlier part of the 20th century and was reflected in positivism and in the hypothetical-deductive methods of science of that time. Ecologists tended to search out undisturbed habitats and species for their studies because, it was thought, these would more accurately describe the equilibrium conditions of the environment. Ecologists tried to avoid situations where human disturbance dominated, except in studies of ecological succession. In the post-modern era we recognize that the world is ever changing, that each situation is relative to its own historical and environmental conditions and that the patterns of nature are circular, dynamic and evolutionary. As a consequence, ecologists have taken a more dynamic perspective of ecological systems in general and have accepted that human-dominated systems are legitimate objects of study. But change is slow. At a recent meeting of the Ecological Society of America, ecologists searching for broad theory or abstractions that would order the subject, an appropriate strategy of the modern era, faced with multiple scales and relativity of cases, declared that ecological systems were chaotic. Notwithstanding the attractive features of chaos theory, this conclusion is not helpful. Ann Spirn expresses the broader view: ‘to see wilderness as chaos provokes fear and prompts flight’ (Spirn, 1998). Ecological systems are not chaotic; they are specific and individual.

Obviously, I am dabbling in a well-known pond of concern. Sir Arthur George Tansley, at the beginning of the 20th century, feared the lack of respectability of ecology (Tansley, 1935). His career was devoted to building the reputation of ecology as a sound and precise physical science. Francesco di Castri, who headed the UNESCO Man and Biosphere program for many years, has suggested that ecology is in a crisis state (di Castri, 1983). Paul Erhlich in his recent book, *A World of Wounds: Ecologists and the Human Dilemma*, deals creatively with this issue (Erhlich, 1997). The list of ecologists concerned about the state of ecology and its role in human affairs is a long one.

I am quite aware that these few words are inadequate to analyze the contradiction I have identified. But possibly they are sufficient to indicate that there is a problem. Now, let me turn to suggestions for resolution of the contradiction. I urge that we embrace the post-modern interpretation and emphasize the uniqueness, the specificity and the relativity of ecological events. This means that we approach each problem directly as a case study without going through theory to a final solution. The sources of the problem may be in public administration, policy, laws, traditions, specific organisms, changed rate processes, history of the site and so on. Each case will be different. As we carefully document the methods and findings and then address and solve problems, we can build up a casebook of environmental experiences. In time these might become a handbook of Ecological Engineering.

The variety of specific approaches is enormous; they parallel the diversity of species and habitats. As a way into the analysis of this diversity, I will describe a simplistic categorization of approaches to ecological problem solving, involving three positions. These will represent two extreme positions and one intermediate position. First is that situation where we have very little information and theory about the problem. Our best strategy is to avoid taking action. Rather, we isolate the problem area and let nature take its course. As natural change occurs, we observe the resolution of the problem as carefully and fully as we can. The descriptive data serve as a case study, which can be extended and tested as other like-problems arise. Over time we may or may not find common aspects of the set of examples which would allow us to take a more active role in problem solving.

Second, at the other extreme is the constructionist approach. In this case the problem is so serious that it demands our intervention and action to reconstruct working systems. In other words, it requires an engineering approach to problem solving. Thinking analogically from construction of a building, we can consider what is required in the reconstruction of an ecosystem. While ecosystems may range in size from the planet Earth to an ecotope, I am thinking of an ecosystem the size of a small lake, stream, wetland, patch of forest or a field. In landscape ecology we call such a small system an ecotope.

Let us consider what this proposal means. Our objective is to be able to reconstruct an ecotope in the same way that we construct a house. The architect, who provides the blueprints which guide the builder, does not work in a vacuum. The architectural design reflects the environment, the legal constraints to building a house, the nature of the adjoining properties and the general character of the space, the taste and money of the future owners, the economic climate, the history of architecture and so on. Many external factors impinge on what can be accomplished.

The design of the structure will provide an inventory of parts of the structure, guide us in our purchases of the parts to be used and, most significantly, tell us how the parts interact with each other. With this information we can calculate the expected costs of the project. The blueprint is a metaphor for what we need in ecology. First, we require an adequate inventory of the system at a biological, chemical and physical level of detail. We need to know what is present and how it is distributed in space/time. We need to understand the niche or the role of each entity and how it is connected and how flexible it is to influences that come from the internal dynamics of the system or from the environment of the system. Then, we need to understand how each entity fits into the webs of influence, how dynamic these relationships are and how fixed. From this information we can make statements about the relation of this to that and the necessity of X or Y being present in the system. From these considerations come the assembly rules that guide us in the sequences of construction and allow us to predict the outcomes of organization.

Obviously this is a big task. And obviously we have been engaged in this task for a long time. And, we are all aware that large-scale programs, such as long-term ecological research, have objectives similar to those I describe. But while all of this is true, we have not been sufficiently successful to change the mood of ecologists. We tend not to think as architects and builders. Our motivation is mixed. Some of us think of nature as a given. We think that nature came from some originating event and as it evolves in time/space we stand in awe of it, observing and recording features of it, as it passes by us. Others of us reject the engineering mode and are repulsed by the idea of manipulating nature according to human designs. We see ourselves as protectors and conservers of nature, not manipulators and builders. Others of us seek to extract from nature resources in a sustainable manner, but the goal is to obtain products for human use. Notwithstanding the ecological engineering approach of William Mitsch, at Ohio State University, USA, few ecologists approach nature from the perspective I suggest here. We are not prepared to think this way (Mitsch, 1992).

Yet if we seek to repair the damage humans have caused by ignorance and greed and create ecosystems that are sustainable, provide the services needed by all forms of life, including humans, and are beautiful and appealing to our spirit, then we require the assembly rules and the blueprints which I have mentioned above.

As an aside, in the second extreme example I discussed above, I am not suggesting that we apply an ecosystem approach to problem solving. The ecosystem approach is opposite the assembly rule approach we are looking for. Let me explain. In ecosystem studies it is conventional to move logically through a nested hierarchy, from higher to lower levels in developing an analysis. For example, a system has a behavior, which is defined as the translation of inputs into outputs. Once we have described the pattern of this behavior for the system of interest, we ask what causes this behavior. To answer this question we enter the system, identify the components we think are related to the behavior, determine how these components are linked together and then through observation and experimentation determine how interacting components collectively cause the system behavior. If we have identified several dominant components that are important we may move to yet a lower level and examine how the subcomponents cause the behavior of the components and then, through them, the behavior of the system. This analytical or reductionistic approach is called top-down research, and yields a mechanistic explanation of how a system functions. The approach is grounded in systems and control theory and is derived from system philosophy (Laszio, 1971).

In contrast, the assembly approach, as I have described it, takes components and, following the rules, assembles them into a functioning system. This is called a synthetic approach and is bottom-up research in the jargon. In ecology a synthetic approach is often grounded in evolutionary theory. Clearly, full explanation of systems requires both approaches.

What has been missing in ecology is an emphasis on the third, middle ground I am discussing. The group of vegetation scientists and ecologists at Yokohama National University, led by our INTECOL President, retired Professor Akira Miyawaki, provide an example of the approach we are searching for. Miyawaki has interpreted a widely known approach to restoration in a Japanese context and has applied it in over 500 cases in more than a half dozen countries in temperate and tropical conditions (Miyawaki and Golley, 1993). This approach is based on two kinds of biological and ecological data. First, it is necessary to describe the inventory of species and their abundance for a specific forest. In Japan remnants of natural forest vegetation have been preserved around temples and shrines. These and other remnants of the natural vegetation have been studied extensively by Miyawaki and his associates and has been described in a set of volumes which cover all of Japan (Miyawaki, 1980). From these studies the group has been able to describe both the potential vegetation and the actual vegetation at a fine scale across the entire country. Second, it is necessary to know how to propagate, plant and establish the tree species of the potential vegetation at a given site. The methods for cultivation of tree species is well known from a horticultural perspective in Japan. Therefore, to restore a forest, it is necessary to study the site and determine the patential vegetation that will grow there and then produce sufficient seedlings of those species to plant a new forest. On many sites Miyawaki plants three seedlings per square meter. The seedlings are 2-years-old and have established long root systems—this is the key to success. Usually tree planting is treated as a local festival and the public places the trees in the ground, thereby creating a personal and societal interest in the planted forest. The close planting results in rapid canopy closure, reducing weeds. Survival is nearly 100%. Growth rates are about one meter per year. No further maintenance is required. As the canopy is raised in height through plant growth other species and plants and animals can invade the site and recreate the herbaceous and shrub layers of the vegetation and the fauna. For example, Aoki and Harada (1985) have shown that the soil fauna is reestablished relatively quickly on these reconstructed sites. The various species compete and thinning occurs. Eventually a forest, with the characteristic diversity of the potential forest, develops.

The result of this approach is that the ecologist can rebuild forest patches quickly with a high degree of predictive success. Miyawaki and his associates know the assembly rules to rebuild the stand of trees. They do not know the assembly rules for rebuilding the networks of other members of the biota, which assemble by chance through selection of dispersing propagules and organisms. This is why this is an example of the intermediate level of problem solving—both the engineering approach and the let-nature-take-its-course method are used to reconstruct forest systems.

My proposal, then, is that ecologists vigorously take up the task of reconstructing terrestrial, aquatic and wetland ecosystems. These ecosystems should be the important ones, on the basis of size, or function, or productivity or conservation, for each ecoregion. The goal of the research must be to learn how to assemble ecosystems quickly, successfully and with reasonable cost. Of course, this research will draw on the results of conventional and theoretical ecological studies but it will also require the change in perception I have mentioned above.

I will anticipate two kinds of objections to this suggestion. First, local scales differ enormously over the Earth surface and there are no general ecoregional systems. Rather each system is locally relevant at a particular time. This means that we must understand how local conditions influence assembly rules. Second, this approach should not be interpreted as allowing the extinction of old growth or long protected ecosystems. Rather, it makes these natural systems even more important because they are the source of the knowledge we have about assembled systems and they serve as the control against which to measure success of assembled systems.

This proposal means that ecologists organize themselves to focus on fewer, many fewer, sites and apply their individual expertise on that site, with the aim of understanding its structure and function sufficiently well so that they can rebuild the system with a relatively high degree of confidence. This ability is essential for human well-being. It is an enormous project if carried out at the global scale. It is worthy of wide public support, including public funding. It challenges the human genome project. It could be the ecologists, superproject at an international scale.

1. For further reading

Please refer to Golley (1995).

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