Restoration ecology

a synthetic approach to ecological research

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of the very basic questions about restoration is: just how difficult is it? Also, to what extent is it going to be necessary to duplicate species composition precisely in order to be considered successful? To what extent will it be possible to substitute species, either for convenience, or for some practical or economic reason, or simply because a species that may have been a component of the native community has become extinct or is unavailable for some other reason. Our results indicate a great deal of plasticity in this matter, suggesting that it is often quite easy to replace one species with another within a community, and that in many cases all you have to worry about is the growth habit and ultimate shape of the plant, rather than a mass of detailed information about the physiological differences among various species.

This, in turn, suggests that the complexity of the task of restoration will vary greatly depending on whether one is trying to reconstruct an ecosystem or actually to reassemble an authentic community, complete with the appropriate species. In fact, if we are not committed to the reestablishment of particular species–species interactions, and are prepared to be content with a certain level of species diversity or productivity, then the rules for reconstructing the system may actually be quite simple. It is only when one begins to be concerned with the precise reproduction of whole, meticulously authentic communities that the problem begins to look extremely complicated.

This may help to explain why those who think about the landscape in terms of ecosystems tend to be a bit more optimistic about our chances of restoring disturbed systems than those whose work is more community oriented.

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23 Reflections on goals and on the relationship between theory and practice

It is a pleasure to have this opportunity to summarize what I see as the main questions and conclusions facing restoration ecologists. Before going on to comment on these matters, however, it might be well for me to describe briefly the perspective from which I view the subject of restoration and restoration ecology. My perspective is twofold: it is partly that of an ecologist who has been working for many years helping to set up national park systems for the governments of Indonesia and several other Pacific countries, and the World Wildlife Fund; it is also partly that of a physiologist working in a school of medicine, another healing profession that shares with restoration the problems of deciding on goals, calculating what we really need to know to be successful, and compromising with practical constraints.

In reflecting on the preceding chapters, it seems to me that we have been focusing on three main questions: what the explicit goals of restoration should be; what is the minimum knowledge needed to achieve those goals; and finally, accepting the premise that restoration not only takes from ecology but also gives to it, we have been considering just what community ecologists can learn as a result of attempts to restore disturbed ecosystems.

Of these three questions, let me reflect first on the last one, which stands a little aside from the other two. What is it that ecology can learn from restoration? From our deliberations, two sorts of lessons have emerged: one is that the traditional approach of ecology is reductionist. We approach the understanding of natural communities by studying certain pieces of them, or by studying certain properties of them. As several authors have pointed out, restoration provides new knowledge not offered by traditional approaches, because restoration is synthetic. It attempts to build communities, and that's justifiably considered the acid test of one's understanding, as Dr Bradshaw has suggested.

This is true because the community you are trying to restore generally won't function until you've supplied all of the necessary elements, including those that nature normally provides but that you may forget about or actually be unaware of. Again, to take an example from Dr Bradshaw, he showed us a slide of a waste heap which, it turned out in the second year of restoration, had been unsuccessfully restored. The reason was an unsuspected need for fertilizer to provide nitrogen that would normally have been provided by lichens. Thus one thing that such restoration efforts can offer to ecology is that unique insight provided by a synthetic approach, which complements the reductionist approach to ecological research.

But there's another set of lessons that restoration can offer ecologists, and that has to do with the severe limitations of the field experimental approach in ecology. There is no doubt that the controlled experiment with preselected perturbations and randomized experimental design is the most powerful tool of ecology, just as it is the most powerful tool of the other sciences. In ecology, however, most of the perturbations that would yield far-reaching insights are either immoral, illegal or impractical. Our field experiments usually run for a very short time – rarely more than a few years – on tiny spots rarely as big as a hectare. Even within these small areas we are confined to those small perturbations, those modest additions or subtractions that we can carry out without being persecuted by our governments, our neighbors, or our consciences.

Think, for example, how much faster community ecology would progress if you graduate students here today weren't restricted to the minuscule field experiments that are now in favor, but if each of you were permitted to select and burn some part of the city of Madison twice a year; or if you could reintroduce wolves into an area of your choice, exterminate the local population of a select species, or dredge and flood a Wisconsin farm and convert it into a marsh. In fact, there is only one way that you get to carry out big manipulations of this sort, and that's by getting involved in restoration projects and taking advantage of the opportunities they offer. These projects vastly expand the spatial and temporal scales of ecological work. They also allow us to work with perturbations far greater than we would be able to work with in any other way. For all these reasons they vastly expand the range of research we can do, the ideas we can test, and the conclusions we can hope to draw from our work.

Those contributions, I think, have emerged from our discussions as the two major contributions of restoration to the science of ecology. Taken together, these two contributions – the synthetic approach and the expanded range of perturbations – are so obvious and so important that I would argue that some training in restoration ecology surely should be part of the training of any ecologist in the future. In short, restoration ought to play the same role in the training of ecologists that practical work in the laboratory plays in the training of organic chemists.

The second of the questions on which our discussions have focused during the last two days is a more difficult one. That is the question, what should the explicit goals of restoration be? This is something restorationists discuss a lot. Words most often used in this volume have been the words "natural" and "self-sustaining". We've heard that the goal of restoration should be to recreate a natural community, or to recreate a self-sustaining community, or perhaps to preserve a community for posterity in essentially its natural state. This goal – this formulation of the goal — isn't a self-evident mandate, however. It is a choice based on values, and it is only one of many possible choices. We know that different people with different values would make different choices about the same site. And even if we adopt the goal of a natural community, it is important to recognize that this goal is extremely ambiguous and needs to be defined very carefully in order to be useful.

The problem is with the very idea expressed in the word "natural". What do we mean by this word? Do we mean untouched by human beings? In fact, almost every place on earth, except the polar regions and a few remote islands, had been severely influenced by *Homo sapiens*, directly or indirectly, long before the European colonization of the world took off in 1492. Which condition is the "natural" condition we are trying to create? In America, for example, is it the condition of the landscape at the moment Europeans arrived? Or the condition that applied a hundred years earlier – or five hundred? Or perhaps three or four centuries later, in 1792, or 1892? Clearly, none of these conditions has more right to be considered natural than any of the others. And we have not yet even considered the influence of American Indians. In some areas it was very great. Is this to be taken into consideration or discounted?

Our decisions in this matter will necessarily be somewhat arbitrary. Moreover, even if we could agree on a definition of "naturalness", none of us wants to restore every community to its natural state. Most of us would applaud restoring Curtis Prairie to its natural state. At the same time, most of us would agree that completely different goals are appropriate in other situations. We would agree, for example, that a farmer making a fish pond should stock it with species selected for maximum productivity rather than with species chosen because they represent the native fauna of Wisconsin as of, say, 1790. And we would agree that a highway engineer should stabilize an embankment with whatever plants do it best, native or otherwise.

In many other cases we might prefer a natural community but have to settle for one that is incomplete or only partly natural because the former natural community, whatever it was, is unattainable. We talk as if this were only an occasional problem. Actually, I think it will turn out to be the rule rather than the exception for at least four reasons. One reason has to do with the statement of Aldo Leopold: *To keep every cog and wheel is the first precaution of intelligent tinkering*. In restoration this is a noble but unattainable goal because many species have already been exterminated. We can't restore ciscos to the Great Lakes, passenger pigeons to our oak forests, moas to New Zealand, or thousands of other plants and animals native to other communities around the world. Some of those plants and animals were of major ecological importance, but they are now extinct.

A second reason why we often can't restore fully authentic natural communities is the presence of introduced species, which would be difficult or impossible to eradicate. It would be nearly impossible, for example, to exterminate starlings and European weeds from the United States, lampreys from the Great Lakes, rats from oceanic islands, deer and opossums from New Zealand, and Nile perch from Lake Malawi in Africa. All of these are introduced species that have had a tremendous effect on the communities they invaded.

Still a third reason why we can't restore natural communities is the problem of scale. We're not restoring the natural landscape but tiny pieces of it. The integrity of these tiny pieces will inevitably depend on influences from outside their borders. Hence restored communities usually cannot be self-sustaining. They'll have to be managed, we humans supplying the inputs that were formerly provided from beyond the boundaries.

For example, Kay Gross has pointed out that a population isolated in a small area may be highly unstable. Restored communities tend to be small, and to support small populations prone to extinction partly because they

depend on resources beyond the boundaries of the community. We are the ones who will have to supply those resources to small, isolated communities to prevent extinctions and so to preserve the community itself. And doing this is a form of restoration – or at least active maintenance.

Ultimately, it doesn't even matter much whether the community is preserved or restored. For example, during my visits to Africa, I have come to realize that the most painful lesson that national park planners there have had to learn is that park boundaries severed the annual migration routes of some of the big mammals, which have a big impact on the parks. This is true, for example, of the elephants of Tsavo National Park. It is also true of the wildebeests of Kruger National Park, and as a result biologists had to give up their idea of considering even huge Kruger as a self-sustaining entity. They have instead had to manage Kruger once the migration routes were severed.

Take another example from our discussion here: prairie patches, whether natural or restored, depend on fires arising beyond their boundaries. But the city of Madison obstinately and disgracefully refuses to let fires in the city just follow their natural course. Hence it's the Arboretum that has to supply its own fires in order to maintain its prairies.

There is another question here, and that is the purely practical question of economics. Even assuming that we could agree on what an authentically restored community would be, and that we knew how to restore it, how much should we invest in achieving this goal? There will be many cases where this will be a legitimate subject for debate. Just what goals are appropriate, given finite budgets, limited time and perhaps inadequate restoration techniques? Any healing art faces this question. In medicine, for example, some victims of heart and kidney disease could be helped by extremely expensive treatments. But how many such patients, and which ones, should receive this expensive treatment? In the case of prairies, for example, should we use prairie restoration funds to weed out exotic plants that are structurally compatible with prairies? Should we instead leave those exotics there and use the money to go restore some other prairie? Or what about the reclamation of phosphate mines in Florida? Wayne Marion and Timothy O'Meara showed us in their poster exhibit (see *Restoration & Management Notes* 3:34) that bird diversity is lower on reclaimed land than on adjacent areas that had been similarly disturbed and then left unreclaimed. This raises a question. What is our goal on these lands? If it is to increase or maximize the diversity of bird species, we are obviously wasting our money – perhaps in an attempt to meet some unrealistic goal of restoration.

The point that I'm trying to make about the goals of restoration can be summarized in this way. If we claim, as we often have in the course of this volume, that the goal is to restore communities to their natural state, or to a self-sustaining condition, we are proposing a fictitious goal that can only create conflict among ourselves, and conflict between us on the one hand and the government and public on the other.

There are simply too many problems and ambiguities about such a goal. Over most of the surface of the earth there are no really "natural", undisturbed communities left. If we arbitrarily define natural to mean "as first seen by Europeans", we face major ambiguities. Even if we did define some nineteenth century condition as the "natural" condition, there are many communities whose species composition we couldn't restore even with an infinite amount of time and money. There are many other communities where even the most ardent environmentalist would adopt some goal other than restoration to the natural state. Finally, even for those communities where we might like to achieve a natural, self-sustaining state, practical considerations force us to lower our aspirations. Yet all these manipulations of communities – to achieve a natural state, a partly natural state, a wholly artificial state – all these manipulations belong to the same applied science. This is implicit, for example, in John Harper's chapter on agriculture and its relationship to ecology. We should not divide this spectrum of manipulations at some arbitrary point and say that the people on the two sides of this arbitrary point should form separate departments, go to separate buildings, and consider themselves as belonging to separate disciplines. Therefore, I see it as a major conceptual task of restoration to spare us the conflict created by fictitious goals and to decide what our real goals are – or, more specifically, to decide on a whole spectrum of real goals appropriate to the spectrum of situations we will have to deal with.

That, then, is the second of the three questions that have come up in the course of our discussion of ecological restoration and restoration ecology. The third of our questions, and it is a difficult one, is what's the minimum knowledge that we restorationists need in order to achieve our goals? Clearly it would be nice to know the detailed ecology of every species and its interactions in the community that we are going to restore. Now that we've heard the detailed accounts of Mike Gilpin on the ecology of *Drosophila* communities in glass bottles, or Kay Gross's account of the ecology of plants in successional fields, I would hate to have to restore any of those communities without at least as much information as Kay or Mike provided us. Restorationists really will find, I think, that it is realistic to seek such detailed ecological information in restoration projects carried out under favorable

conditions, where there is plenty of money and a fair amount of time, and the goal is to restore the genetic diversity of small pieces of endangered habitat with a modest number of species. This may be the case, for example, in restoring Wisconsin prairies, or perhaps in restoring the endangered native bird communities of Hawaii.

In other cases, though, there are so many species, and we know so little about the ecology of most of them, that we will obviously have to settle for much less. New Guinea rainforests, for example, have about 600 bird species, 200 mammal species, and thousands of plant species, including unknown numbers of undescribed ones. Even for most of the described species, we know nothing about their reproductive biology. Thus it is clear that restoration will often be a crisis discipline that allows no time at all for background ecological studies.

For example, in the mid-1970s the government of Papua New Guinea, told its ecologists, "We, the government, together with a timber company, have already begun clear-cutting the rainforests of the Gogol River. Secondary growth is starting to spring up and you may begin restoring those rainforests right now".

Another example: in 1979, the Indonesian government told the World Wildlife Fund, myself and other consultants, "Next year we, the Indonesian government, are going to award the timber leases in Indonesian New Guinea. In six months give us the finalized national park plan for Indonesian New Guinea". The problem was that large areas of Indonesian New Guinea had never even been entered by biologists. We gave them advice within six months, but obviously some of that advice was based upon pure guesses, even about what species occurred where.

These demands for instant advice are not unusual. In many parts of the world they are the rule. The government will say, "We want to plan a national park in this area of 3000 square miles. A biologist has never been there. Here are two weeks and $1000. Find out what is there and what we need to plan the national park, conserve it, and restore any damaged areas". We are going to be seeing this over and over again in the future. Hence, it seems to me that the most important problem that restoration ecologists face is: given some limited amount of time and money, what is it that we most urgently need to know in order to restore – and manage – a community? Just what ecological information should we try to acquire for that money and within that time? Also what are the details that we will ignore and package into a black box for which we will settle on knowing only the input and the output?

We've seen examples of this approach here in this volume; for instance, John Aber's measurements of soil mineralization within plastic bags. John has proceeded in this way because he is convinced that for certain purposes it is important to know the rate of mineralization, and that one can get along without knowing exactly how it takes place. To me, confronted with these two-week deadlines in Indonesian New Guinea, this seems to be a good example of how to use time and money efficiently. However, these examples may cause some dissent arising from the differing needs of pure science and applied science.

Let's make clear, however, what the differing goals and methods of pure science and applied science are, and let's make clear what we as ecological restorationists are doing. In pure science the goal is to understand the world. There are no time limits. The definition of the scientific method is to make general statements that are supported by adequate evidence. Scientists are judged by the connection between their evidence and their conclusions. Thus, if your conclusions are based on inadequate evidence, you are simply practicing bad science.

In applied science, on the other hand, the goal is to solve a practical problem, using whatever scientific information is available. There are time limits. You are judged by the quality of your results, not by the quality of your reasoning and the scientific evidence that led you to those results. If your methods and reasoning don't lead you to good results, that's what makes you a bad applied scientist.

In doing restoration, we are doing applied science, not pure science. In the process we will continually be asking ourselves what is the information that we really need in order to get high-quality results, given the constraints on our information-gathering ability.

Just to summarize, then, I see four conclusions as having emerged from our discussion. First, restoration has two important things to offer to ecology. It offers the opportunity to learn by synthesizing communities rather than reducing or analyzing them; and it offers the opportunity to carry out major experimental manipulations, ones that ecologists would never be permitted to carry out under any other circumstances. At the same time, restoration ecology now faces two major conceptual challenges. One is to decide what we really mean by our goals when we pretend that we are restoring natural, self-sustaining communities – which we rarely, if ever, are. The second is to decide, given limited amounts of time and money, what we most urgently need to know in order to achieve our goals. These are important, urgent questions for restoration that clearly have important implications for the science of ecology as well.

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