Ecosystems (1999) 2: 277–280

ECOSYSTEMS

Managing Earth's Ecosystems: An Interdisciplinary Challenge

Gretchen C. Daily* and Paul R. Ehrlich

Department of Biological Sciences, Stanford University, Stanford, California 94305-5020, USA

Key words: academic departments; careers; economics; institutional change; transdiscipinary collaboration.

In the beginning, there was the universe; from the Middle Ages on, there have been academic disciplines to study it. When early inquiries and discoveries were being made and the universe appeared a neat, clockwork Newtonian place, the Western scientific disciplines—primarily physics, chemistry, geology, botany, and zoology—seemed to fill the bill. But problems weren't long in appearing. The boundaries between chemistry and physics and between botany and zoology began to break down early on, and, by the middle of the last century, those between chemistry and biology (a descendent of botany and zoology) lost their sharpness. Considerable inertia may build up in institutions, however; it may be particularly strong in those sheltered from competitive market forces, such as universities. Channels developed to direct flows of capital into university schools and departments; infrastructure and discipline-oriented reward systems were established, and positive feedbacks favoring established disciplines naturally developed, amplifying the career value of a disciplinary focus and deepening the channels controlling resource flows.

Thus a conservative division of the world of scholarship has been fostered. This conservatism influences virtually every aspect of scholarly inquiry, from the framing of research problems, to funding and conducting investigations, to publishing the findings where they will reach the targeted academic audience, and to communicating the importance of the work more broadly to undergraduate students, policy makers, and the public.

Let's consider first the framing of research problems. Since the Middle Ages, the process of cultural evolution has generated a body of nongenetic information sufficiently vast that no one person could hope to grasp more than a tiny fraction of it. If human beings are going to learn more about how the world works, and better direct their collective understanding to the long-term service of humanity, the world of knowledge must be subdivided somehow. Disciplines therefore are necessary. At the same time, few significant human problems lie within the boundaries of current disciplines. A question such as "what is consciousness and how does it relate to emotions?" might be considered primarily in the arenas of neurobiology and philosophy, but important dimensions clearly also lie in fields such as genetics, endocrinology, evolution, and behavior. Similarly, a problem such as "how can the harmful environmental impacts of human activities be greatly reduced?" might seem squarely situated in demography, ecology, and economics (to readers of *Ecosystems*, anyway), but further consideration quickly takes one into fields of engineering, sociology, psychology, anthropology, political science, law, and ethics, to name just a few.

Failure to recognize the footprint of such problems on what might be thought of as a multidimensional, multidisciplinary surface could lead at best to silly, naive "answers" and, at worst, to bad policies with serious societal consequences. Ecologists must be particularly wary of this. Arguably the most critical problem in ecology today is to establish a scientific basis for making human activities ecologically sustainable. Yet rarely are issues in this area approached systematically, because to do so would obviously require forays far afield into disciplines in which ecologists typically get little or no training. It is much easier—and more rewarding professionally in many tangible ways—to limit one's explorations to better mapping of the "terra cognita."

Received 4 February 1999; accepted 3 March 1999.
*Corresponding author. e-mail: gdaily@leland.stanford.edu

The low level of interaction between ecologists and agricultural scientists is but one example—but a particularly telling one—of the failure to address adequately a critical problem. Food production is arguably humanity's most important activity, and it certainly causes—directly and indirectly—many of humanity's greatest ecosystem impacts through land-use change, facilitation of biological invasions, and the widespread application of synthetic chemicals. At the same time, the agricultural sector depends heavily, compared to other sectors of the economy, on ecosystem services. Yet, relative to the importance of the problem, very little agricultural or ecological research is directed toward characterizing the relationships between land-use intensity and ecosystem service production. This traces in part to the present lack of economic incentive for such work in the private sector, where much agricultural research is undertaken; in academia the problem seems to be more one of fashion. On a closely related topic, the future course of life on the planet—and the provision of important ecosystem services—will depend to a large extent on which species can survive in human-dominated agricultural landscapes. Even in the domain of conservation biology, however, relatively few researchers venture outside of remaining "natural" habitats onto farmland. Thus little is known about countryside biogeography—the diversity, abundance, conservation, and restoration of biodiversity in human-dominated habitats.

How could a more interdisciplinary approach to addressing such problems be fostered? It is, of course, always theoretically possible to assemble transdisciplinary teams (groups of cooperating disciplinarians), but that often presents a difficult challenge of finding people willing and able to work together. With the rewards flowing down disciplinary lines, all too often only very senior people may be in a position to participate. Nonetheless, with effort, such collaborations are possible and may be very successful. We have been fortunate at Stanford University, for instance, in getting ecologists, economists, business people, and legal scholars to work together on transdisciplinary problems. The same goes for a group of economists, ecologists, and other scholars centered around the Beijer Institute of Ecological Economics of the Royal Swedish Academy of Sciences.

In both cases of transdisciplinary collaboration, four things have been required. First is the commitment of senior people who have little to risk professionally and are anxious to involve bright junior people in the effort. The second is funders who appreciate the need to foster interdisciplinary collaboration and who are willing to back experimental efforts. The third is persistence—mutual understanding and cooperation build slowly. And the fourth is circumstances of social interaction and long-term association that allow friendships to develop.

The latter seems particularly central to the success of these enterprises, much more than we would have expected at the outset. At Stanford, traditions of allocating fully half of the time in transdisciplinary seminars to discussion and to supplying ample refreshments in an informal setting, made possible much more rapid meaningful interchange with colleagues than would have occurred in standard seminars. Friendships developed across departmental lines that rarely were crossed previously. Similarly, the Beijer Institute often gets people together at multiday workshops where groups work, eat, and drink together, often in an attractive setting. And it's no accident that one of Stanford's most successful transdisciplinary seminars is known as "The Chocolate Group" in honor of a bonding factor that does not bear directly on solving the world's problems. With bonding, transdisciplinary work gradually becomes interdisciplinary, as the participants gain expertise in each other's home areas in the course of the interactions.

The biggest job at the beginning of any transdisciplinary enterprise is establishing communication. Originally ecologists and economists were separated by differences in world view clearly related to differences in their training. Considerable mutual instruction, translation of jargon, and patience were required before the problems themselves were clear to both groups and a joint attack on those problems could be launched. For example, before economists could get interested in the valuation and safeguarding of ecosystem services, they had to become informed of the nature and importance of those services. Before ecologists could participate productively in the effort, they had to learn about economic principles and methods of valuation, and about the role of institutions in mediating human interactions with the environment. As important as the communication of knowledge is the explanation of the limitations of that knowledge. But gradually a common ground on which to build has become established.

Another prerequisite of doing successful transdisciplinary (and eventually interdisciplinary) work is to choose collaborators from among those who are respected in their home disciplines, whose contributions to joint work one can trust. The story of the mathematical biologist whom the mathematicians thought must be a great biologist and the biologists thought must be a great mathematician is not

apocryphal. Any of us who have worked in interdisciplinary areas have had experiences with people who are drawn to the fuzzy interface between disciplines because of a relative lack of success within the home discipline. Maintenance of standards is more difficult in interdisciplinary work, but it is far from impossible. Papers may require more peer review, and the reviewers should include well-established disciplinary leaders to ensure that there are not technical flaws that would obviate the interdisciplinary results. Sound review also may require interdisciplinary leaders who are alert to disciplinary biases in choice of problems or kinds of analysis, and who can referee where two disciplines have different standards. We believe the problems of cross-disciplinary peer review are not different in kind from those of disciplinary peer review, but they do require more time and attention from both editors and reviewers.

Finding appropriate places to publish interdisciplinary research is a more difficult problem. Most journals that publish interdisciplinary work are relatively new and do not (yet) have large readerships or world-class reputations. This makes it hard to reach desired audiences; it also makes it difficult for young interdisciplinary scientists to acquire the publishing credentials required for promotion and tenure. Right now one more overexamination of a trivial issue published in *Ecology*, *Science*, *The American Economic Review*, or *Current Anthropology* will count more with a department chair or dean than a pathbreaking article in *Ecosystems*. Sad, but true. We have often had long discussions with our colleagues in economics about where to publish our joint efforts; this can be a serious problem even for people well established in their home discipline. It takes time for a journal to gain an excellent reputation, but in the long run we believe that only by establishing and supporting journals with new disciplinary orientations can the problem be satisfactorily solved. *Ecological Economics*, after an intellectually somewhat shaky start in the opinion of disciplinarians on both sides, is clearly rising in quality and acceptance. The same is true of *Conservation Biology*.

A more fundamental solution to fostering interdisciplinary research than forming transdisciplinary teams would be to train scholars to pay much less attention to the standard boundaries on the multidisciplinary surface. Obviously it is not possible to begin training people thoroughly in all of the disciplines that bear on the maintenance of ecosystems. There is no way any more to be a "Renaissance Person" even in that rather narrow area of human culture. But other approaches are possible. So far, we've been trying to establish a mind-set among our graduate students that involves exploration of important interfaces between population biology and other disciplines. Graduate training is centered in theoretical and empirical population biology, and the bulk of any Ph.D. dissertation is aimed for publication in disciplinary journals. But students are encouraged to develop the applications of their work to societal issues, and to discuss these as appropriate in disciplinary papers and also to develop separate, more complete publications on them. Students are exposed to the concepts, methods, and frameworks for analysis used in economics and other disciplines in both courses and transdisciplinary seminars. They know, for instance, that the demography, economics, and sociology of local peoples are as important to preserving the biodiversity in an area as the design of regional reserves—and that, in fact, when they tackle a conservation problem the two must be considered hand-in-glove. We hope that our students will become true ecological interdisciplinarians—scientists with a firm grounding in one or more technical areas within population biology, but who always mentally place their area of expertise into a much broader context. Ideally, they will apply ideas from the social sciences or elsewhere if there is no need for deep technical analysis outside of their field, but they will recognize such needs when they arise and should be comfortable doing collaborative research with social scientists or other environmental scientists outside of their areas of expertise.

Another approach, which we tend to use more at the postdoctoral level, involves drawing the training boundaries differently on the multidisciplinary surface so that a student develops comparable expertise in adjacent areas of two classic disciplines—say ecosystem ecology and macroeconomics or conservation biology and rural sociology. This approach has the potential advantage that, if used frequently, could help to soften and realign disciplinary boundaries. But within the structure of most universities, it is more difficult to institute logistically—at least at the graduate student level—than the former approach. The reason is simple, and we suspect our experience will apply broadly. We are in control of the training of our students, and as long as they meet minimal departmental criteria, we can allow them relative freedom in the exploration of literature, coursework, and research topics. The development of joint programs among different disciplines requires much more work—recruiting appropriate faculty members and making formal arrangements. At present this is much more complicated (and possibly hazardous), especially from a graduate student's viewpoint.

We reemphasize the No Renaissance People Principle—that the world of scholarship *must* be broken up into disciplines to make progress possible. There is nothing at all wrong with being a disciplinary scholar—indeed both of us get our greatest joy doing research within rather narrow confines in population biology. What is wrong is considering disciplinary boundaries fixed forever rather than eternally flexible, and punishing those in various ways who chose to tackle problems that cross the boundaries of the moment. The conservatism that was useful in the past is a luxury society can no longer afford.

Considering how difficult fostering interdisciplinary research is, that it is gaining ground in the face of the academic odds is very cheering. Another bright spot is that the public is interested in the big picture painted by science, and that picture is rarely painted by a single discipline. We find, therefore, that communicating interdisciplinary results to the public is generally easier than communicating disciplinary results. That should also provide a useful handle for gaining the funds required to conduct research in new areas—and if we are to manage Earth's ecosystems sustainably, that will be a *sine qua non*. In our own experience, students are desperately interested in interdisciplinary problems and will eagerly undertake research on them with the slightest encouragement (as long as there is a prospect of a job at the end of the tunnel). We think there is a brilliant future for such research, both because we have so far to go, and because more and more people are beginning to realize that we must make the trip.