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Interdisciplinary Research: Maintaining the Constructive Impulse in a Culture of Criticism

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We approach the benefits and burdens of interdisciplinary research (IDR) from the perspective that science involves both constructive and critical approaches. The constructive aspect generates concepts, theories, and data to understand the observable world, while criticism tests the internal consistency of understanding and its fit to the observable world (Pickett and others 1994).

IDR is the linkage of phenomena, research approaches, and conceptual tools that had previously been pursued independently (Parker 1993). Such linkages produce new research questions, new approaches to problems, new theories, and new generalizations. Therefore, IDR emphasizes the constructive aspect of science. Both the critical impulse and the constructive impulse are needed for scientific knowledge to grow and to be correctable (Weissman 1989). Yet, criticism is emphasized by the falsificationist philosophy of Popper (1968) so often lionized by ecologists. Ironically, the seemingly opposing view of Kuhn (1970) can encourage the search for paradigmatic "big game" and thus also support the critical impulse.

If the critical tools are given undue weight, as seems to us to be the case, then the constructive impulse may be underdeveloped by comparison. The habits of mind (Gruber 1989), that is, talents, skills, and motivations, that satisfy the constructive impulse may not be in the top drawer of the tool kit of most ecologists. This essay will explore the benefits and burdens of IDR by touching on three broad topics: (a) the value of IDR to ecology; (b) the difficulties of conducting IDR; and (c) key to successful IDR.

Interdisciplinary Research Is Beneficial to Ecology

There are three realms in which IDR can benefit ecology (Pickett and others 1994). It is important to highlight these different realms because the same terms are usually used to denote the specializations within at least two of them. Therefore, the complexity and range of opportunities for IDR *within* ecology may not be apparent.

First, ecology itself is an extraordinary broad science across which IDR is possible. Ecology is synthetic and eclectic, encompassing subject matters and concerns shared with a number of other disciplines (Likens 1992). Ecology links with geochemistry at the abiotic extreme and to genetics at the biotic extreme (Figure 1). Between those poles, it combines key background knowledge and approaches from physiology and population biology, for example. Some of the differences in ecology are broad chasms that present opportunities for linkage. Ecosystem and population ecology, for example, are especially ripe for such joint exploration (Jones and Lawton 1995). This first realm of integration is a kind of "bridge building."

The second realm for IDR in ecology is the range of spatial and temporal scales the science covers. Ecology is concerned with processes on the bio-

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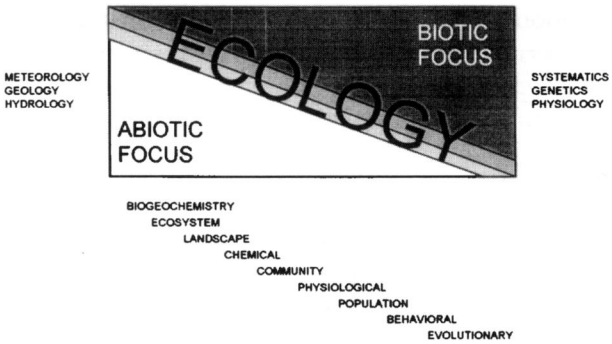

Figure 1. A schematic for the breadth of ecological science. The vertical dimension represents the differential combination of abiotic and biotic phenomena in specialties within ecology, which are shown on the horizontal dimension. At either end of the horizontal dimension are physical and biological sciences that bound ecology, and with which it commonly interacts. Modified with permission from Likens (1992).

spheric and continental scales, such as the regulation of elemental fluxes or the distribution of biotas. Global ecology, ecological biogeography, and landscape ecology are relevant here. On the temporal dimension, broad scale phenomena are separated among the specialties of evolutionary ecology and paleoecology, for example. Much progress has been made in bridging the scales implicit in such disciplines as paleoecology and contemporaneous community ecology, for example (Foster and others 1990). Many more opportunities for IDR exist across the scales ecology addresses. This opportunity for IDR can be called "ladder building."

Whereas the first two realms for IDR exist within the broad scope of ecology, the third arena for IDR extends beyond the boundaries of ecology. However, the benefits and burdens are similar to those encountered in crossing specialties and scales within ecology. This third realm is the linkage with disparate disciplines. One example of an extramural integration well under way is ecological economics (Costanza 1991). Another that seems ripe is a combination of human demography and the demography of natural sciences (Cohen 1995). However, the obvious similarities of demographic approaches in social science and ecology (Ehrlich 1997) should not blind ecologists to less obvious bridge points. In fact, the search for human social processes that link with the processes of community, ecosystem, and landscape ecology is quite promising. Ecologists will have to envision the linkage as going well beyond the subject matter of biological ethology, to embrace an understanding of social institutions, political dynamics, and the feedbacks including such institutions (Grove and Burch 1997). Formal and informal institutions, institutions with the glacial pace of the law and with the ephemerality of a community building encounter on a neighborhood street, and institutions with a local address versus those that act as spatially diffuse networks are all involved.

If IDR has such an array of benefits for ecology, how might it be assessed? Using the IDR link between ecology and social sciences of institutions, we propose five questions that may help evaluate the success of any IDR. First, does the IDR stimulate a systems approach for integrating sociocultural and biophysical systems? This occurs by describing the internal behavior of the systems and their interactions with each other in terms of flows and cycles of critical resources (for example, energy, material, nutrients, information, population, capital, or labor) and allocation mechanisms (ecology, exchange, authority, tradition, and knowledge). This is essential for moving beyond purely biophysical models, which limit research to intermediate variables and proximate causes of human ecosystem patterns and processes, and to address underlying, causal sociocultural variables (McKendry and Machlis 1993). Second, does the IDR relate sociocultural and biophysical patterns and processes at different scales (Lee and others 1990; Allen and Hoekstra 1992; Fox 1992; Burch and Grove 1993; Levin 1993)? Third, by articulating the relationships between sociocultural and biophysical patterns and processes, does the IDR research address different types of system change, such as resilience, resistance, persistence, and variability (Pimm 1991) over time and space (Burch 1988)? Fourth, does the IDR include the spatial measurement, classification, and analysis of sociocultural and biophysical patterns and processes (Zonneveld 1989; Grove and Hohmann 1992; Machlis and others 1997) Fifth, does the IDR fit within a broader understanding of ecological systems for social and biological scientists? Specifically, in adapting the contemporary paradigm of ecology (Pickett and Ostfeld 1995) to assess integration with social science research:

1. Human ecological systems are never closed or self-contained;
2. Human ecological systems are not self-regulating;
3. Stable point equilibria are rare, although some systems of sufficient size and duration may exhibit stable frequency distributions of states;
4. Change is rarely deterministic, such that human ecological systems are stochastic and future conditions have varying levels of probability;
5. Disturbances are a common component of human ecological systems, though some distur-

Table 1. A Continuum of Interdisciplinary Research Association with Desired Ideals and Real Constraints

Research Strategy	Ideal	Real
Traditional	Need graduates in both humanities and sciences.	Hire scientists and technicians and display artworks at headquarters.
Multidisciplinary	Coordination of independent efforts.	Token disciplines affiliated with effort.
Cluster	Professional schools combine many disciplines to solve problems.	A gaggle of disciplines share a dean and get their paychecks from a central office. Students are the only connective tissue.
Interdisciplinary	Cooperation with mutually beneficial arrangements—directed to solving specific problem.	Has a complicated decision structure not unlike the United Nations. Much time spent in meetings and developing a unified paradigm, which is never completed.
Integrated	Collaboration in working jointly to resolve a common problem with shared plan, conceptual framework, and responsibility for implementation.	Like United States melting pot that has dissolved into angry debates over multiculturalism. Hybrid unity is apparently not politically acceptable.

bances are not frequent on the scale of human lifetimes;

6. Human ecological systems are self-aware, and nongenetic information plays a important role in system dynamics. Humans have the ability to develop and communicate descriptions of present realities and knowledge of causes and effects with each other.

These become the key beginning assumptions for building an effective bridge between community, landscape, and ecosystem perspectives in ecology and the social science of human institutions.

Interdisciplinary Research Is Hard

We explore four of the most prominent reasons we believe IDR to be difficult. These include the subtlety of disciplinary diversity within ecology, the lack of a conceptual framework in early IDR, the initial need for inductive approaches, and the time required.

First, new IDR lacks an articulated framework. In established areas, conceptual frameworks indicate the role of the empirical assumptions, carry the structural assumptions, show how facts and hypotheses, models, and expectations are linked, and indicate the scope to which each generalization or model applies (Pickett and others 1994). Frameworks are often hierarchical, showing how the knowledge and models are linked from the general to the specific. Articulating a framework is important for unifying a field of study, for prioritizing research agendas, and for exposing inconsistencies. Conceptual frameworks are major deductive tools in established areas. Emerging ID areas do not benefit from established frameworks, and are thus slowed.

Second, IDR requires inductive approaches. Often even the basic patterns that suggest sophisticated hypotheses are lacking in new areas. For example, the spatial patterns of an array of human and social capital, such as institutional structures and networks, are not available for regions that ecologists and social scientists wish to jointly study. The relationships between the social capital and ecological processes are needed to develop mechanistic hypotheses and models. However, such inductive approaches are apparently undervalued in ecology.

Third, IDR takes a long time because it is a group process (Parker 1994). Nurturing an effective group requires much effort. Shared goals, focus on a common problem, a common conceptual framework, integration of knowledge, and integration of group resources are hallmarks of successful group research (Parker 1993; Table 1). This goes beyond the commonly stated goal of developing a "common language" that so often motivates exploratory interdisciplinary activities. A common language may still hide divergent assumptions. Therefore, the development of a "common meaning" (Bohm 1996) may better represent the job of group dynamics for IDR. An example of the complexity of the group effort required for IDR is the necessity not only to incorporate key features of the concepts and data from contributing disciplines, but also the need to winnow components that, although important to the individual disciplines, are not needed in the synthesis. In ecology, the early development of the ecosystem concept involved the shedding of organismic assumptions from community ecology (Tansley 1935).

The four burdens, outlined above, that IDR must carry are the same burdens that any scientific

construction must bear. The burdens are difficult enough in themselves, but they are exacerbated when the critical impulse, which is well developed in scientific training, acts too soon during the construction process. Of course, an emerging IDR project will be incomplete, will contain erroneous components, and may have indistinct scope. All of these failings must be ultimately corrected. However, to yield to the critical impulse too soon in the process may thwart an IDR effort. Premature or overzealous application of the critical impulse is akin to allowing the editorial impulse to act too soon in the process of writing. The result is often "writer's block" and a perpetually blank page. The blank spaces at the frontiers of ecology, especially with the social sciences of institutions are becoming more and more glaring in this increasingly human-dominated world.

What Makes Interdisciplinary Research Work?

The constructive motive of science leads us to briefly list the key tactics that contribute to IDR. The fundamental need is to recognize that the support for IDR may differ from that of the usual, disciplinary pursuits. The fact that IDR is a group process suggests that the time frame for investment, success, and reward may be longer than for disciplinary research. Rewards must be given for nurturing an IDR group as well as for production of concrete group products. Groups exploring an IDR frontier will, like the explorers of a literal frontier, produce a map. Common concepts, frameworks, and questions will characterize the scientific map of the new frontier. Journals can recognize that even the tentative maps are valuable products to share during IDR exploration.

Identification of a common problem is a hallmark of success in IDR. Such common problems differ from the mere transfer of an accepted problem from an established discipline to an interdisciplinary frontier. Borrowing can be helpful to IDR, but the potential for different dimensions to emerge from the combination of various perspectives means that IDR teams should be ready to generate common rather than translated research questions. Early in the development of an area, most of the issues may be conceptual and methodological, with empirical issues emerging from a clear conceptual base. The shared focus on conceptually well-motivated data is a powerful motivator for further integration.

A common research site can be a stimulus to IDR. Note that the evolving models and explanations may extend well beyond the bounds of the initial research site. However, a shared site, such as a watershed, a city, or the like, can help a team to focus and to identify processes that they can likely unify and share (Foresman and others 1997).

Common methods may promote IDR. In the emerging synthesis of social sciences and community ecology, the use of "participant action research," in which knowledge is generated in cooperation with and using the insights of residents of an area, is an important tool (Whyte 1991). This approach is unfamiliar to ecologists who assume that they have no interaction with the systems they study. Interaction with residents and organizations in an inhabited landscape can lead to important questions, interpretations, and extensions of specialist research.

Both deductive and inductive approaches are part of IDR. Well-established and mature specialties may rightly emphasize deductive approaches, given their well-articulated frameworks and widely known fundamentals. However, early IDR must construct just such a knowledge base. The inductive approach helps build the comprehensive roster of factors that guides mechanistic and causal hypotheses. Such rosters become the "usual suspects" that scientists round up when they construct specific models and design experiments.

The use of hierarchies of models and theories is important in IDR. First, analogies that match in scale and scope can be productive. For example, the analogy between a neighborhood and an ecological patch is a tool for initiating social and ecological IDR (Grove and Burch 1997). Once the analogy is identified, then the middle level theories that each speciality uses can be identified, along with rigorous linkages sought between those theories. It is important to search for middle level theories because the most general theories in each of the contributing disciplines are likely to be so abstract that they are difficult to link clearly. Similarly, the most detailed, spatially localized models are likely to contain so much detail that the potential hooks that might be used to link disparate areas are simply too difficult to identify.

An example of an interdisciplinary approach that illustrates some of these features is the study of ecology *in* the city versus ecology *of* the city. The study of the ecology of the city is the more comprehensive of the two approaches. Some examples include the classic ecosystem models of cities such as Hong Kong, in which a flux and transformation model of material and energy was developed for the city as a whole (Boyden and others 1981). However, other approaches to ecology, such as the focus on patchiness, which developed in ecology after that

study was completed, were not available to help understand Hong Kong. Therefore, in terms of the understanding of ecological processes as sensitive to spatial pattern, there is the opportunity to form a more comprehensive understanding. From the social perspective, comprehensiveness suggests inclusion of cultural, institutional, resource, social dynamic, and various forms of capital. The complete understanding of the city as an ecological system would include all these perspectives: (a) the city as an input–output flux system, (b) as a spatially organized landscape, as (c) a socially structured system, and (d) as a nonequilibrium dynamic system. Ecology in the city is important and interesting (Stearns and Montag 1974), but it may neglect many of the causal features and spatial and historical contingencies that in fact influence the behavior of even the "green" components of a metropolitan area (Flores and others 1997).

One of the most important ways to promote IDR is to recognize the limits that the usual review procedure forces on IDR. Such limits may be difficult for scientists to deal with because they point to the social context of the scientific enterprise. The common social habits of xenophobia or group loyalty may constrain IDR. This would not be a problem if it weren't so easy to hide xenophobic biases in seemingly objective statements about the quality of research. Exposing hidden assumptions and biases behind the valuative statements in reviews is important.

One of the most significant systemic limits of IDR is that most leading journals are disciplinary territory. The loyalties and biases—more charitably assumptions and scope—held by reviewers and editors are likely to be those of relatively narrow disciplines rather than the motivations of bridge builders or ladder makers.

There is a variety of ways in which the potential biases against IDR can be compensated. One is for a journal, a professional society, or an entire science to have a vision for the value, role, and needs of successful IDR. It is especially important that the editors have a clear and well-articulated vision about IDR and its place in their journal. When reviewers are selected and charged to evaluate such manuscripts claiming to contribute to IDR, those reviewers must be chosen or educated to share that vision. The degree of development of an evolving IDR area and the contribution of a particular manuscript to that evolution must be known.

The development and use of an effective vision to promote the publication of good IDR is no easy feat. The habits of journals, editors, and reviewers seem to emphasize the critical approach to manuscripts. So many scientists see as their primary tool a critical eye, that it may be difficult to find a constructive editorial pen. Perhaps a different set of instructions to reviewers should accompany papers attempting IDR. In any event, the key ingredient to success of IDR in most journals, if they have the courage to embrace it, may be for the editors to act on a vision, rather than to act as scorekeepers for sets of ad hoc reviews.

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