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Two Cultures of Ecology

[C.S. (Buzz) Holling](#)

University of Florida

> *This editorial was written two years ago and appeared on the main page of Conservation Ecology before any articles were published in the journal. It was meant to help shape the focus for the journal. As we have recieved a number of requests to cite this editorial, we are republishing it in this issue in order to give it a permanent "home" that can be referenced. It is certainly as current now as it was then.*
> *C.S. Holling*

Ecological science is in transition. Previously separate schools of ecology are being linked across scales − from physiological to landscape. Policy and practice are being integrated in ways that demonstrate that science benefits as much as does practice. Biological ecology is being combined with the environmental sciences and with social and economic understanding. It is a transition made possible by a maturing body of theory, methods, and examples. And it comes at a time when the policies needed to harmonize the interaction between people and nature occurs at unfamiliar scales from regional to global. It is this transition in ecology that provides the focus for *Conservation Ecology*.

As in any transition, there are extreme proponents of one view or the other, one approach or another. Much of that is exaggerated by limited experience. Ecologists are just beginning to develop the range of experience needed to link science, policy, and politics. Policy people are largely unfamiliar with ways to recognize the novel interactions now emerging between economic, social and ecological systems. Because the science is in transition, there are not only conflicting voices, there are conflicting modes of inquiry and conflicting criteria for establishing the credibility of a line of argument.

The speed of the transition is being driven by the speed at which regional and global changes are eroding the planet's natural heritage. To some, this leads to appeals for advocacy. But the journal will not be a place for advocacy, however important the issue. Rather the journal will focus on the foundations of science, policy, and practice upon which informed action can be based.

Conservation Ecology is designed as a place to develop and explore the novel theories, methods, research, and policies that are needed to underpin the conservation, restoration, and maintenance of the natural heritage that sustains life and human opportunity. This focus requires some research in what might be called applicable science − a mix of theory, basic research, and illuminating applied examples. It requires analysis and examples of novel ways to develop incentives such that individual self interests better reinforce social goals of conservation. And it requires experiments in novel ways to develop citizen science as an antidote to the power lobbying that now so distorts the use of information in the democratic process.

That is why the partners in the development of *Conservation Ecology* on the Board of Editors are scientists and scholars whose interests cover a range from genetics to planetary dynamics, from resource management to economic policy, from theory to practice. And it is why we have a co−equal board, the Ecological Policy Council, composed of senior executives from business, government and the non−profit sector − individuals from around the world with vision, practical experience, an environmental interest, and a systems perspective.

I called *Conservation Ecology* a place. Beyond the hype of the devotees of the World−Wide Web and the internet, there does seem to be the possibility to develop a sense of place that engages an international consortium of scientists, scholars, executives, and citizens. It builds on the only existing culture that could truly be called global. That is the culture of international science, where differences in history, language, and experience enhance the common foundation all scientists share in ways to acquire, apply, and sustain knowledge for the betterment of humanity.

That is why we plan to develop and test various experiments in using the World Wide Web and the internet in a set of Conservation Ecology Projects. These are designed around two programs: science policy dialogues on special topics and regional satellite sites as part of a distributed learning network. Once these projects are underway, *Conservation Ecology* will have become less a journal and more an institute−without−walls with an extended family of participants.

The focus and the projects of Conservation Ecology have been chosen to facilitate the transition in ecological science by bridging gaps between two very different ways of viewing the world. These are particularly clear in the philosophies of two streams of science. The tension between those two is particularly evident in biology, and the reason lies in the principle features of each as summarized in the accompanying table. One is brilliantly represented by the advances in molecular biology and genetic engineering. That stream of science promises to lead to health and economic benefits of biotechnology but also to a journey on an uncertain sea of changing social values and consequences. It is an analytical stream of biology that is essentially experimental, reductionist, and disciplinary in character.

TABLE 1. Comparing the two cultures of biological ecology

ATTRIBUTE	ANALYTICAL	INTEGRATIVE
Philosophy	•narrow and targeted •disproof by experiment •parsimony the rule	•broad and exploratory •multiple lines of converging evidence •requisite simplicity the goal
Perceived organization	•biotic interactions •fixed environment •single scale	•biophysical interactions •self−organization •multiple scales with cross scale interactions
Causation	•single and separable	•multiple and only partially separable
Hypotheses	•single hypotheses and nulls rejection of false hypotheses	•multiple, competing hypotheses •separation among competing hypotheses
Uncertainty	•eliminate uncertainty	•incorporate uncertainty
Statistics	•standard statistics •experimental •concern with Type I error	•non−standard statistics •concern with Type II error
Evaluation goal	•peer assessment to reach ultimate unanimous agreement	•peer assessment, judgment to reach a partial consensus
The danger	•exactly right answer for the wrong question	•exactly right question but useless answer

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The other stream is integrative and is represented within biology by evolutionary biology and by systems approaches that extend to include the analysis of populations, ecosystems, landscape structures, and dynamics and, more recently, further extends to include biotic and human interactions with planetary dynamics. The applied form of this stream has emerged regionally in new forms of resource and environmental management where uncertainty and surprises become an integral part of an anticipated set of adaptive responses. It is fundamentally interdisciplinary and combines historical, comparative, and experimental approaches at scales appropriate to the issues. It is this combination that provides the necessary foundations for any kind of global science, if for no other reason than we have but one globe to live on, for the present, at least, and cannot experimentally manipulate lost pasts. It is a stream that is fundamentally concerned with integrative modes of inquiry and multiple sources of evidence.

It is this stream that has the most natural connection to related ones in the social sciences that are historical and integrative. It is also the stream that provides the bridge between analytical science, policy, and politics.

The properties of each stream exaggerate the tensions between them − one is reductionist and certain, one is integrative and uncertain. The first stream is a science of parts − e.g., analysis of specific processes that affect specific variables − populations of individual species, levels of nutrients, flux of gases. It emerges from traditions of experimental science where a narrow enough focus is chosen in order to pose hypotheses, collect data, and design critical tests in order to reject invalid hypotheses. Since it is experimentally based, the scale chosen typically has to be small in space − the plot of a few square meters, the bagged small tree − and short in time − certainly not longer than the professional life of the experimenter or grant.

Where the scales are appropriate to the question, as in experiments that manipulate properties of lakes or small watersheds, the analytical stream has already become an essential partner with the integrative stream. Partly as a consequence, effective policies at regional scales have been developed and applied, as witness the multi−national actions to control acid rain emissions in Europe and North America..

The goal of the science of parts is to narrow uncertainty to the point where acceptance of an argument among scientific peers is essentially unanimous. It is appropriately conservative and unambiguous, but it often achieves that by being forced to be fragmentary and small in scale. In ecology, it provides essential bricks for an edifice but, by itself, not the architectural design.

The other stream is a science of the integration of parts. It uses the results of the first, but identifies gaps, develops competing causative hypotheses, and constructs and uses simulation models as devices for exploration and experimentation over scale ranges that are impossible to achieve by experiments in nature. The integrated consequence of each competing hypothesis is evaluated by using information from planned and unplanned interventions in the whole system or by comparing and contrasting extreme examples.

The goal is to narrow the range of possibilities by generating and testing predictions of different competing hypotheses. In the process, some are rejected, some further confirmed, some modified, to develop a credible line of argument from multiple lines of evidence. The scales chosen are dictated by the question and not by practical limitations of experimentation.

The premise of this second stream is that knowledge of the system we deal with is always incomplete. Surprise is inevitable. There will rarely be unanimity of agreement among peers − only an increasingly credible line of tested argument. Not only is the science incomplete, the system itself is a moving target, evolving because of the impacts of management and the progressive expansion of the scale of human influences on the planet.

Of course, knowledge should be mobilized to reduce uncertainty wherever that is possible. But ecosystems and the human activities associated with them are inherently uncertain. Part of that is because of incomplete knowledge of novel interactions across space and time, and of novel relationships between nature and human behaviors. Part is because management changes the system being managed. Successfully managed systems are ever−changing targets because they release the resources for new kinds of human opportunity and they expose new classes of human risk.

In principle, therefore, there is an inherent unknowability, as well as unpredictability, concerning ecosystems and the societies with which they are linked. There is, therefore, an inherent unknowability and unpredictably to sustaining the foundations for functioning systems of people and nature.

Inevitably, therefore, information and decisions are vulnerable to being manipulated by powerful interests. While scientists do not thereby need to become politicians, they do have to be sensitive to political and human realities, and to recognize how theories, different modes of inquiry, and different rules of evidence can facilitate, hinder, or destroy the development of constructive policy and action.

Recommendations have to be based on responsible judgment and interpretation of the burden of evidence. The International Panel on Climate Change is an effective, organized example of that process of accumulating relevant knowledge, interpreting it by a community of scientists from a number of disciplines, and disseminating it for the advancement of both science and policy.

Both the science of parts and the science of the integration of parts are essential for understanding and action. Those more comfortable in exercising only one of these have the responsibility to understand the other. Otherwise the science of parts can fall into the trap of providing precise answers to the wrong question and the science of the integration of parts into providing useless answers to the right question.

Finally, in ecology, practitioners of both streams of endeavor must develop a clear eyed perception of, and experience with, policy, politics, and the wonderful, frustrating, and sometimes destructive forces that motivate people and their interactions with nature.

RESPONSES TO THIS ARTICLE

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Address of Correspondent:
C.S. (Buzz) Holling
Department of Zoology
University of Florida
223 Bartram Hall
Gainesville, Florida 32611−2009 USA
Phone: (352) 543−6955
Fax: (352) 392−3704
holling@zoo.ufl.edu

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