In *The Scientist*, January 22, 2001. A response to J.R. O'Connor, 2000. "Why Ecology Lags Biology", *The Scientist* **14**:35.

Raymond J. O'Connor attributes what he calls the "faltering progress of ecological research" to lack of creativity on the part of ecologists and a failure to follow the examples of more "successful" sciences (e.g., molecular genetics and physics). We agree that ecology would benefit from a greater emphasis on generality and conceptual unification. However, we take issue with both the contention that ecological science has failed to progress, and that the approaches of other disciplines can be applied to ecology to produce more worthwhile science.

O'Connor's evidence that ecology is unsuccessful takes three forms. First, he contends that ecological hypotheses are focussed on natural history and not general hypotheses about how ecological systems work. O'Connor cites three ecological studies that employ "rigorous analysis and logical thinking" and contends that these examples are anachronistic. These studies very well represent the state of the art in ecology. Even a casual look at recent issues of *Ecology* or *The American Naturalist* shows that most studies published in major journals are quantitative and mechanistic. In addition, many synthetic studies are made possible only by the collection of descriptive data. For example, the Human Genome Project, which O'Connor touts as a triumph, is the ultimate testament to the power of natural history. The single largest "big science" project of modern biology, a description of "what is" rather than a test of hypotheses about how things work, will allow for tremendous advances in medicine. Progress toward conceptual unification in ecology also demands adequate descriptive data. The collection of these data should not be undervalued.

Second, O'Connor uses the global persistence of environmental catastrophes such as the collapse of fisheries as a sign that ecological science has failed. The fact that environmental problems persist reflects many social, economic and ecological factors, not just poor science by ecologists. Many fishery failures reflect conscious decisions by government agencies to overexploit stocks, or to ignore the council of fisheries biologists (1). The persistence of outstanding problems is also not unique to ecology. Does the fact that people still get sick reflect bad medical science, or the complexity of disease biology combined with social factors?

Third, O'Connor claims that ecology is weak because it has failed to produce a breakthrough on the magnitude of the human genome project. While NSF's Biocomplexity Initiative was allotted $50 million in 2000, the Human Genome Project received $360.6 million from the U.S. Government (2). In addition, much of the effort to map the genome is being funded by private concerns. Some ecology is supported by other agencies such as E.P.A., however the fact remains that the resources spent on biomedical science vastly exceed those for ecology. Many of the apparent differences in progress between ecology and molecular biology are attributable to the disparity in how much support these programs receive.

The types of questions we address make ecology fundamentally different from physics or molecular biology. The "question" motivating the Human Genome Project is: "What is the sequence of base pairs in human DNA." Examples of ecological questions include: "What will be the effects of global warming on life on earth," "How much fishing will cause extinction of Pacific salmon," or "How does species diversity affect the functioning of ecosystems." The answer to the genome question is definite, not subject to uncertainty, and easily studied in a laboratory using standard methods. The answers to the three ecological questions are context dependent, subject to considerable uncertainty, and cannot be studied under controlled conditions. For example, the answer to the fishing question might well depend on the answer to global warming question, thereby magnifying the uncertainty. That the genome problem has a definitive solution reflects the fact that the answer can be spelled with the four letters A, T, C, and G of DNA. The answers to the ecological questions are considerably more complex.

We believe that much of the perception of ecology's weakness stems from the fact that the field includes both basic and applied branches. Although the three ecological questions mentioned above have no simple, definite answers, they are nonetheless of tremendous importance to society. Some studies are aimed not at producing general theories, but at solving important practical problems. O'Connor's example of another study of "the fall feeding habits of white-tailed deer in Maine" might be conceptually empty, but could still be of tremendous value for managing deer herds in Maine. Generality should be a primary goal of ecologists, and we agree with O'Connor that it needs further emphasis. However, generality comes from creating broad, mechanistic theories, and from testing them in many systems. Relevance comes from applying these ideas to questions that are important to society. The application of ecology to real issues is a sign of its strength, not its weakness.

1. J. Roughgarden and F. Smith. 1996. Why fisheries collapse and what to do about it. PNAS **93**: 5078-5083.
2. http://www.ornl.gov/hgmis/project/budget.html

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