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Forging a Common Agenda for Ecology and Paleoecology

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Ecologists recognize the importance of taking a long-term view. That is why the Long Term Ecological Research (LTER) program at the National Science Foundation (NSF) has been heralded as such a success. But with the scale and urgency of the challenges our society and our planet face today, we need to take a still longer view, peering into the deep past and incorporating the lessons the geologic record has to teach us. Understanding how humans affect ecological systems, and predicting how those systems will respond to our impacts, requires using geohistorical data.

That is the conclusion of a new report from a committee of the National Research Council (NRC). The report, *The Geological Record of Ecological Dynamics: Understanding the Biotic Effects of Future Environmental Change,* is available online (*http://books.nap.edu/catalog/11209.html*).

Biological scientists and earth scientists are entering into collaborations more and more as they recognize how much they can gain from one another's disciplines. Ecologists are learning techniques for obtaining and evaluating geohistorical information, and paleontologists are learning about ecological phenomena amenable to analysis in the geological record. Our common focus is the information that can be extracted from geohistorical sources. These sources include fossils, ice cores, tree rings, cave deposits, pack rat middens, and sediments from land, lakes, and oceans. A wealth of proxy indicators, from pollen to stable isotopes, serves to reconstruct environmental conditions with remarkable precision. And new sampling strategies and modes of analysis reveal the biology, ecology, and distribution of many ancient species and communities.

In just the past decade, analyses of environmental and biotic information from geohistorical sources yielded valuable information on the following issues, among others:

- The historical effects of overfishing on marine species and communities
- The causes of megafaunal extinction pulses on multiple continents
- The ecological consequences of damming major rivers
- The impacts of human arrival on Polynesian island fauna
- The influence of acid precipitation from industry on modern-day ecosystems
- The use of fire by prehistoric peoples to manage ecosystems
- The human and natural contributions to salmon population declines
- The effects of changing land use on the Chesapeake Bay

Certainly the collaborative use of geohistorical sources can help scientists continue to address such questions. The scientific and societal challenges we face today, however, *demand* that such collaboration be promoted and encouraged strongly and explicitly. We need more such biogeoscience, and we need it now.

Consider global climate change. Our society relies on ecosystem services derived from the functioning of natural systems, so if humans are on the verge of dramatically altering those systems, we'd better be able to predict the consequences. Yet we are proceeding into uncharted waters, and cannot be sure whether the biotic responses noted so far can be neatly extrapolated into the future, whether trends will accelerate, whether thresholds will be crossed, or whether something completely unexpected will transpire. Scientists need to improve the ability to predict the consequences of climate change on ecological systems.

The geologic record can help us. Our planet's climate has gone through so much variation over thousands and millions of years that the geologic record offers many alternative states that can be studied. Without this record, we would be limited to a measly few decades or centuries of climatic observation—hardly much time for a range of climate variability to occur. By expanding the range of climatic possibilities that can be studied, the geologic record allows scientists to address the two outstanding questions in climate change science: How can we predict the consequences of conditions that will be outside our historical reference? And to what extent is climate change driven by human activities rather than natural processes? The geologic record is vital to answering both of these questions.

In the face of such urgent questions, collaboration between life scientists and earth scientists continues to be hamstrung by the usual difficulties of crossing disciplinary boundaries. Even when researchers have the knowledge and willingness to cross these boundaries, there is rarely institutional incentive to do so. In addition, some biologists worry that geological dating methods and the quality of the fossil record may be too unreliable to address ecological questions. These may have been legitimate concerns 20 years ago, but dating technologies and sampling strategies have

advanced to the point today where ecological questions are waiting to be pursued with geohistorical data.

The NRC report urges that scientific agencies of the federal government respond to these critical needs with a strong investment of funding and new programs. We urge the NSF, the US Geological Survey, and other agencies to take these priorities to heart. The report recommends organizing efforts under three broad initiatives:

1. *The geologic record as an ecological laboratory.* Geohistorical sources provide a wealth of information on long-term ecological patterns, and on ecological patterns under environmental conditions very different from today's. By providing a window on a range of "alternative worlds," the geologic record allows ecologists to test which principles in ecology are truly general and which are specific to present-day conditions.

2. *Ecological responses to past climate change.* Predicting how species and communities will respond to climate change is vital for agriculture, forestry, biodiversity conservation, and a host of other pursuits that sustain our civilization. We may already be experiencing climatic conditions the planet has not seen for hundreds of thousands of years. Only by peering back into deep time will we find analogies to future climate conditions, and data on how ecological systems responded in those cases. Thus, to predict the biotic consequences of climate change, we need the geologic record.

3. *Ecological legacies of societal activities.* We know that human impact has altered ecological systems, but determining what changes are attributable to our impact and what changes result from natural variability can be difficult. Witness the debates over climate change and over why North America's large mammals went extinct. The geologic record lets us compare modern-day ecological dynamics to those that existed before the advent of the human species. Such contrasts help researchers tease apart the contributions of human and nonhuman factors in driving ecological change. The geologic record is the only window on prehuman baseline conditions, since human influence on modern-day environments was in full swing long before scientific monitoring efforts began. Knowing such baseline conditions is of particular interest for ecological restoration efforts.

A sampling of the NRC report's specific recommendations to government agencies includes these suggestions:

- Establish a program of geologic time ecological research (GTER) projects, based on the LTER model. GTER projects would focus the attention of diverse researchers on particular time intervals, habitat types, critical regions, or environmental gradients. GTERs could be targeted to areas with modern-day conservation relevance; such a project in Florida's Everglades region, for instance, could assist with ongoing restoration plans.

- Integrate geohistorical data into current LTER projects to greatly expand their ability to elucidate truly long-term ecological patterns.

- Establish a postdoctoral program whereby recent PhDs in ecology take positions with mentors in geology (and vice versa) in an explicitly interdisciplinary program.

- Integrate geohistorical research into the National Ecological Observatory Network to help meet its mandate of ecological forecasting.

- Promote collaborative working groups along the lines of the National Center for Ecological Analysis and Synthesis, and interdisciplinary conferences along the lines of the National Aeronautics and Space Administration's astrobiology conferences.

- Fund the online databases and physical collections that serve as critical storehouses of publicly accessible data.

The increased commitment by government agencies that we are requesting will need to be sustained over roughly a decade to induce lasting scientific change and to bring to fruition the vital cross-disciplinary collaboration we envision. Such commitment will prove to be a great bargain. There is nothing more important for society today than to be able to accurately predict future ecological dynamics and the consequences of our actions. Using the riches from the past that the geologic record has to offer is an indispensable means to that end.

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