



Proactive ecology for the Anthropocene

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Abstract

The rapid, directional global changes that characterize the Anthropocene provide unprecedented opportunities for ecologists and other scientists to discover new paradigms that shape our understanding of the ways that the world is changing. These paradigms will likely focus more strongly on interactions, feedbacks, thresholds, and model uncertainty than on steady-state dynamics and statistical uncertainty. We advocate a shift in ecology and other disciplines to a more proactive leadership role in defining problems and possibilities in a rapidly changing world rather than being relegated to a reactive role of trying to fix the problems after the horse has left the barn. This requires not only renewed commitment by ecologists (and other citizens) to a more proactive ethic of environmental citizenship but also institutional changes in education, the scientific review and funding processes, and promotion and tenure processes to encourage and celebrate those who seek to shape trajectories toward greater ecosystem and social resilience and well-being.

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The Anthropocene brings us into a Brave New World (Huxley, 1932) of science. At the age of 26, Charles Darwin traveled on the Beagle to places that few scientists had seen. The striking patterns of diversity that he saw opened his eyes to the discovery of evolutionary processes that operate everywhere and had shaped the world since well before the dawn of science. As today's young scientists launch their scientific careers, they do so in a world that is changing more rapidly, directionally, and globally than at any time since science began. Although the processes are probably no different than they have always been, just as in Darwin's world, the dynamics are changing in unprecedented ways. In this non-equilibrium world, science will undoubtedly develop new paradigms that shape our understanding of the ways that the world is changing. For the scientist entering graduate school today, observable patterns will probably change more dramatically during her or his scientific career than during the previous millennium. What an exciting time to be a scientist!

Many current ecological paradigms are predicated on steady-state assumptions. For example, many ecologists assume that ecosystems approach a steady-state carbon stock, where carbon inputs from photosynthesis equal carbon losses from respiration, and net ecosystem production (NEP, the difference between photosynthesis and respiration) approaches zero (Chapin et al., 2006; Odum, 1969; Woodwell and Whittaker, 1968). Similarly the composition of plant and microbial communities is often assumed to approach steady state in late succession. However, recent studies show that late successional forests continue to accumulate carbon (Le Quéré et al., 2009; Luyssaert et al., 2007; Xiao et al., 2008) and change in species composition through local extinction and invasion of new species (Parmesan et al., 1999; Post, 2013). The ecology of the Anthropocene must determine the critical controls over these directional changes in ecosystem structure and function and the circumstances in which these changes precipitate irreversible transformation to novel states, many of which have no past analogues (Hobbs et al., 2013; Scheffer, 2009). In times of rapid change, we often don't know what will happen next, so science needs to focus more strongly on interactions, feedbacks, and thresholds than on steady-state dynamics. This may benefit from exploration of scenarios to identify game-changing processes and thresholds, i.e., greater focus on model uncertainty rather than on statistical uncertainty.

Designation of the Anthropocene as a geologic epoch (Crutzen, 2002) provides a formal scientific framework for the increasingly obvious fact that human activities interact strongly with environmental, ecological and social changes at local to global scales. The time is past when ecologists can study "pristine" ecosystems, ignore human roles in the dynamics of those systems, and expect their results to be broadly applicable. Ecology must be part of an interdisciplinary suite of disciplines that embraces the linkages between social

and ecological components of social-ecological systems, often focusing on those linkages as aspects where scientific study is likely to provide the most novel insights.

Ecology has a much more important role to play in Anthropocene dynamics than simply observing and understanding change. Stewardship is the shaping of trajectories of change to foster ecological and social resilience and well-being (Chapin et al., 2009; Chapin et al., 2011). Ecologists, other scientists, policy makers, managers, and civil society all have important contributions to make in shaping trajectories of change away from catastrophic risks and thresholds toward more sustainable outcomes. The time for loading-dock science, in which the scientist produces knowledge for someone else to use, is over because the decisions that shape important changes in social-ecological systems require insights and dialogue among all groups. There are many distinct roles that ecologists can play in stewardship according to their interests and personal philosophies. These include traditional roles such as conducting use-inspired research (i.e., research that advances fundamental understanding, while providing societally relevant insights) (Stokes, 1997), education, and outreach. The “broader impacts” criterion for evaluating research proposals at the National Science Foundation indicates that the conduct of societally relevant research is expected of all scientists.

However, ecologists can go further and play other roles that create a more rigorous scientific foundation for stewardship. These include active dialogue with other stakeholders, including politicians, policy makers, and civil society, about the processes driving social-ecological change so as to foster mitigation of undesirable changes that can be prevented or minimized as well as potential transformations that might move social-ecological systems toward more desirable trajectories and acceptable risks. These less customary roles of scientists raise fundamental questions about the role of science in society. Scientists often pretend that their investigations are objective and value-free. Although this may be substantially true in the process of drawing conclusions from scientific evidence, scientists are unquestionably motivated by values in deciding what questions to research and how and with whom to communicate the outcomes. The ethical boundaries between science and advocacy are fluid and worth re-examining in light of the world’s rapid human-driven changes. An individual can constructively operate at multiple points along the science-advocacy spectrum, as long as there is clear awareness and communication about the roles being played.

Erica Fernandez’s honors thesis at Stanford University provides an example of interdisciplinary action ecology with potential to guide policy and promote community actions (Fernandez, 2012). The Yucatan Peninsula has experienced anthropogenic deforestation and biodiversity loss since early colonial times. Direct effects on the physical environment include a dramatic decrease in forested land, while indirect effects include changing Maya perceptions, understanding, and conservation of forest ecosystems. Contrary to expectations, Ixil, which supported monocultures of the henequen, an Agave harvested for fiber, had higher species richness, perhaps due to introduction of opportunistic species on disturbed lands, compared to Maya communities near *Reserva San Nicolás*, where there was less disturbance. Retention of traditional ecological knowledge was variable, perhaps due to location, immigration, and other socioeconomic factors. This study shows that working landscapes can support substantial biocultural diversity through multiple interactions of spatial heterogeneity associated with land use change and urban development, the type of species present in the landscape, and the age and degree of intergenerational knowledge transmission. Equally important, the project led to a field study by local community members to assess and improve their ability to recognize plants of their region as well as discussions of ways that formal education of youth could be changed to better prepare Maya children for a rapidly changing world, while maintaining their traditional knowledge and values.

In Alaska, a Community Partnership for Self-Reliance and Sustainability has integrated the efforts of four rural indigenous communities with the University of Alaska Fairbanks and the Alaska Native Science Commission (Cochran et al., 2013). The goal of the partnership is to foster *in-reach* from communities to the university. Communities provide *their* vision of ways in which they can be more independent in achieving their cultural and livelihood goals, and university research groups provide expertise to assist in meeting these community goals, when communities request this. The community partnership provides the opportunity for communities to reflect carefully on their long-term goals and to connect these goals with research groups seeking to make their research findings more useful to Alaskan residents. Collaborative projects have emerged around renewable energy, subsistence fishing, and community relocation to escape erosion associated with climate change.

At another scale, the Ecological Society of America has established a speakers’ bureau to foster greater dialogue between scientists and communities of faith. Potential speakers are trained not only in ecology but also in patterns of dialogue that build bridges rather than barriers between scientists and religious groups that seek unbiased sources of information about the changing world (<http://www.esa.org/enjustice2/projects/faith-communities/>).

In summary, we advocate a shift in ecology and other disciplines to a more proactive leadership role in defining problems and possibilities in a rapidly changing world rather than being relegated to a reactive role of trying to fix the problems after the horse has left the barn. This requires not only renewed commitment by ecologists (and other citizens) to a more proactive ethic of environmental citizenship but also institutional changes in education, the scientific review and funding processes, and promotion and tenure processes to encourage and celebrate those who seek to shape trajectories toward greater ecosystem and social resilience and well-being.

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