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Editorial

Amphibian Decline: More Support for Biocomplexity as a Research Paradigm

The global decline of amphibians is an issue that not only unifies major recurring themes of this new journal – emerging infectious diseases, globalization, and complexity – but challenges conventional thinking about one of the fundamental environmental issues of our time, the loss of global biodiversity. A sharp decline of amphibian species was first noted by herpetologists about 25 years ago. Since that time, experts on the biology, ecology, and conservation of frogs and salamanders have been puzzled by evidence pointing to a synchronous pattern of worldwide population declines. Why all the puzzlement and surprise? After all, representatives of virtually all plant and wildlife taxa have been dwindling markedly due to habitat loss, overharvesting, and pollution since detailed record keeping on global biodiversity began in the 1960s. Indeed, the 2004 Red List of Threatened Species (http://www.redlist.org) reports the number of species at risk had swelled to over 15,000 – up from 10,000 since just the 1996/98 reporting period. Yet, a closer look at the data shows cause for alarm: of the 1874 vertebrate species added to the list 1646 are amphibians, although amphibians represent just 10% of the 57,739 vertebrates scientifically described! Part of this vastly disproportionate increase is due to more effort being focused on field surveys of amphibians in recent years. Yet, the data nevertheless reflect a real asymmetry in amphibian declines relative to other vertebrates—in fact, a quantum leap in the number of amphibian species in decline. That science has been taken by surprise at this dramatic drop in amphibian numbers says much about our poor state of knowledge about biodiversity, in spite of the important gains in our understanding of the extinction process. Historically, seminal developments in conservation science and why they could not anticipate this abrupt amphibian decline are revealing and worth recounting.

These developments mainly began with the remarkably influential 1967 book by Robert MacArthur and E. O. Wilson, *The Theory of Island Biogeography*, which inspired a generation of biologists to investigate what determines species' persistence in the face of nature's vagaries and human co-option of natural habitat. The "species-area effect," a major focus of the book, predicts that smaller areas have fewer species because their smaller populations are more vulnerable to extinction due to chance demographic, genetic, and environmental events. The quantitative relation between species number and area – and the underlying local extinction-immigration dynamics of species' populations – has since become one of ecology's fundamental principles, as eloquently described by Michael Rosensweig's important synthesis published in 1995, *Species Diversity in Space and Time*. The early applications of species-area models to species loss projections also helped launch the modern conservation science movement. Prompted by the implications of these findings, a number of us who had been involved in developing them, as well as captive animal experts, conservationists, and animal geneticists, converged in San Diego for the "First International Conference on Research in Conservation Biology" in the late summer of 1977. The terms *conservation biology* and *biological diversity* (later contracted to *biodiversity*) first emerged from this meeting. I suggested the former, believing that the new conservation science needed a name legitimizing it as a subdiscipline of biology. The latter was introduced by Thomas Lovejoy in the foreword to the proceedings *Conservation Biology: An Evolutionary – Ecological Perspective* make the point that not just species but Earth's immeasurable ecological and genetic variety were at risk. The research paradigm catalyzed by meetings, the proceedings helped frame much of the conservation research agenda for decades to come. Yet, that the framework was too narrow is evident by the amphibian decline. Among other things, the biology of the extinction process envisioned under this paradigm tended to downplay the role of infectious diseases in extinction, to that mainly as a potential "proximate" factor. That is, once a species had its numbers and geographic range reduced by deterministic, "ultimate" causative factors like habitat loss, factors like the chance introduction of a pathogen could extinguish the remaining few local populations. However, as Schloegel et al. suggest in this volume, this conventional view of the role of infectious disease in the extinction process may need revision.

The possibility for an exclusive role of infectious disease in some amphibian extinctions and our surprise at the abruptness and magnitude of amphibian species decline are becoming an all too familiar reminder of the inherent uncertainty and nonlinear behavior of biological systems – as well as the inadequacy of conventional analytical approaches to predict such behavior. This is especially the case now that cross-scale influences such as exponentially increasing rates of regional and global transport are capable of transforming a local pathogen transmission event into a pandemic on the time scale of weeks or months (by contrast to the years or decades once required). *Biocomplexity* was coined by Rita Colwell, and as is now well known by many of us, the idea captured by the term became the impetus for a research program of the U.S. National Science Foundation under her directorship. This term was conceived to convey both the need for a deeper understanding of our planet, in which human society is seen not simply as an external stressor but as an integral part, and that conventional scientific constructs are too simplistic to capture our planet's complexity. The notion of biocomplexity contrasts with that of biodiversity in its conception of our planet as a coupled human-natural system and in its view of the dynamic relationships among the biological and physical parts, from microbes to monsoons, as being at least as important as the parts themselves. Understanding the population biology of extinction is no less essential to addressing the problem of global biodiversity loss under this new paradigm. Yet, as our surprise at the abrupt decline of amphibians makes all too obvious, the parts – populations of microbes and their vertebrate hosts – and their dynamics cannot be treated in isolation from the whole – ecosystems and the changes they are undergoing on a global scale. As the biocomplexity paradigm holds, *emergence* and *hierarchy* are fundamental properties of biological systems. The former cannot be anticipated without considering the latter, as the much underestimated role and aptly named phenomenon of emerging infectious diseases demonstrates.

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