

Profile

Examining the Links between Biodiversity and Human Health: An Interdisciplinary Research Initiative at the U.S. Environmental Protection Agency

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Abstract: Under the U.S. Environmental Protection Agency's mission to protect human health and the environment, the agency seeks to conduct research on the structure and function of ecosystems and to improve our understanding of the processes that contribute to the sustained health of the nation's ecosystems and the well-being of human populations. Changes in biodiversity can profoundly impact the ability of ecosystems to provide clean water, energy, food, recreation, and other services that contribute to human well-being. In addition, changes in biodiversity can affect the transmission of infectious disease to humans, particularly vectorborne diseases such as malaria and Lyme disease. The Environmental Protection Agency's new initiative supports interdisciplinary research to characterize the mechanisms that link biodiversity and human health and to use this knowledge to develop integrative tools and approaches for quantifying and predicting these relationships. Research on these links can have an important impact on our view of biodiversity and how we manage resources to protect human and ecosystem health.

Keywords: biodiversity, ecology, infectious disease, emerging disease, interdisciplinary

INTRODUCTION

Humans depend on natural ecosystems and the services they provide, including food, energy, clean air and water, and recreation. Conserving biodiversity, including genetic, species, and ecosystem diversity, is a primary means of sustaining these services, especially in response to changing conditions (Loreau, 2001; Millennium Ecosystem Assess-

ment [MA], 2005a). Yet our actions in the past 50 years have changed these systems to an unprecedented degree, altering habitats, reducing biodiversity, and putting ecosystem services at risk (MA, 2005a). Estimated rates of species extinction are as much as a thousand times higher than average in the fossil record, levels that are unprecedented outside of mass extinction events (Pimm et al., 1995). The net loss of populations and individuals may be several times greater than the rates of species loss (e.g., Hughes et al., 1997; Thomas et al., 2004).

At the same time, new infectious diseases appear to be emerging at an increasing rate (Wilcox and Gubler, 2005; World Health Organization, 2005). They include new diseases such as severe acute respiratory syndrome (SARS) as

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well as reemerging diseases that have expanded in geographic range, such as West Nile virus (Fauci, 2005). A common feature of emerging infectious diseases is that they are associated with anthropogenic changes to the environment (Patz et al., 2004; MA, 2005b). What are the underlying mechanisms of this emergence, and do changes in biodiversity play a role?

There is scientific evidence to support this relationship. The loss or extinction of large predators because of hunting and land-use change can increase the population of a particular vector or host. This loss can result in a greater prevalence of pathogens among hosts, and, consequently, pose an increased risk of transmission to humans (Dobson et al., 2006). It has also been shown that the loss of specialist predators can affect the health of animal populations, as diseased individuals can survive longer and increase the potential for transmission (Packer et al., 2003). Conversely, when nonnative species are introduced into a system, they can alter ecosystems, impact biodiversity, and change native host–parasite dynamics (Telfer et al., 2004). Introduced pathogens and vectors can also cause high levels of mortality in wildlife and humans (van Riper and van Riper, 1986; Lounibos, 2002).

With much of their life cycles occurring outside of the human host, waterborne and vectorborne pathogens are particularly sensitive to environmental conditions. For example, eutrophication and overfishing can contribute to an abundance of intermediate snail hosts of schistosomiasis (Picquet et al., 1996; Madsen et al., 2001). Other studies suggest that species and habitat diversity can reduce the transmission rates of vectorborne diseases. LoGuidice et al. (2003) developed empirically based models that suggest increasing rates of *Borrelia burgdorferi* tick infection, the pathogen associated with Lyme disease, as host biodiversity declines. In a Louisiana study, increased diversity of nonpasserine birds, which are less competent reservoir hosts compared to passerines, was associated with decreased West Nile virus infection in mosquitoes and humans (Ezenwa et al., 2006). Another recent study of West Nile virus in the Baltimore–Washington, DC area showed that mosquito feeding preferences rather than the diversity of available hosts was the dominant factor in transmission patterns (Kilpatrick et al., 2006).

Land-use changes can lead to multiple impacts on disease transmission, especially if vector species adapt to newly created niches in different ways (Chang et al., 1997). Vittor et al. (2006) found that numbers of *Anopheles darlingi*, the most efficient vector of malaria in the Peruvian

Amazon, and human biting rates were higher in deforested sites than in forested areas, independent of population density. Do mosquitoes have a preference for newly deforested sites, and if so, why? Or does the finding have more to do with fish ponds that are associated with new settlements in forest-cleared areas?

OPPORTUNITY AND APPROACH

Shifts in biodiversity on all levels, from genes to ecosystems, may play a role in infectious disease transmission. More research is essential to help decision-makers assess the effects on human disease transmission from changes in biodiversity. In response to this need, the U.S. Environmental Protection Agency (EPA) has developed a new, interdisciplinary research initiative to understand the qualitative and quantitative relationships between anthropogenic stressors, changes in disease host or vector biodiversity, and infectious disease transmission to humans. This research will involve the characterization of the environmental and social factors that contribute to biodiversity change, the population dynamics of animal reservoirs and vectors of disease, biological mechanisms that influence disease transmission to humans, and the processes by which infectious diseases emerge and spread. Research that addresses the following questions can advance knowledge on how anthropogenic stressors, changes in biodiversity, and human health are linked:

How are vector infection rates affected by changes in host richness, relative abundance, and community composition? How are vector infection rates affected by these changes over time?

Does the disease vector acquire infection primarily from a particular host within a community? If so, how is this preference affected by the availability of certain hosts compared with a larger host community?

How do changes in host diversity, with varying levels of competence for pathogen transmission, affect vector abundance?

How do answers to the above correspond to human transmission rates?

How are human behaviors related to changes in host and vector biodiversity and to risk of infectious disease?

Are there susceptibility factors among animal hosts, vectors, and humans that contribute to disease transmission?

Research can help identify the types of data that are necessary to better monitor and predict the risk of infectious disease from anthropogenic changes to biodiversity. Studies can also shed light on how global drivers such as climate change may affect host–pathogen dynamics and disease emergence in humans. New knowledge on the biodiversity–health relationship can lead to multiple benefits, such as the promotion of sound land-use practices and the design of environmentally based (nonchemical) strategies to reduce infectious-disease incidence. Non-chemical strategies will reduce the use of pesticides as a control method of vectorborne diseases and could result in less pollution to land, air, and water. EPA’s initiative is a timely opportunity to develop innovative and integrative tools and approaches to support decision-making that can reduce risks to both health and the environment. More information on the research initiative can be found at <http://www.epa.gov/ncer/biodiversity>.

Interdisciplinary Forum and Workshop

In September 2006, in co-sponsorship with the Yale Institute for Biospheric Studies’ Center for EcoEpidemiology, the Smithsonian Institution, and the World Conservation Union, EPA convened an interdisciplinary forum and workshop of researchers, practitioners, and decision-makers in conservation biology, ecology, public health, and earth and social sciences. The public forum was an outreach effort to increase awareness of the connections between biodiversity change and human health. The forum consisted of presentations on various topics related to biodiversity and human health, including research on biodiversity decline and increased incidence of infectious diseases, the role of social capital in managing environmental resources, soil biodiversity and human health, protecting biodiversity for potential medicinal value, wildlife trade and risks to biodiversity, valuation of biodiversity related to disease, and potential applications for observing systems to monitor and predict risks to environment and health. (For presentations, see <http://www.yale.edu/yibs/biodiversity.html>.)

Workshop discussions were held to identify case studies that could test the links between biodiversity and health, mechanisms that connect them, and guiding research questions across different systems. Participants in a second breakout session developed a blueprint for a spatial method to study the links between biodiversity loss and the emergence of infectious disease. A third group discussed

how response strategies to infectious-disease outbreaks by public health managers can affect biodiversity. Through a variety of perspectives and disciplines, the forum and workshop participants identified the need for further research to characterize mechanisms that could connect biodiversity and health and the anthropogenic stressors that affect them.

Request for Applications

EPA has released a Request for Applications (RFA) to examine the links between anthropogenic alterations of ecosystems, changes in disease host or vector biodiversity, and infectious disease transmission to humans. Sponsored research will focus on systems in which changes in biodiversity are hypothesized to be an important driver or trigger of risk of infectious disease. The RFA requires an interdisciplinary approach to conducting research, integrating data on ecosystems, human health, and anthropogenic stressors by incorporating tools and methods from the ecological, health, and social sciences. Researchers must also consider how research results can be used by decision-makers to protect human health and the environment.

EXPECTED RESULTS

Through sponsored long-term research, pilot studies, and EPA-initiated projects, the following results are anticipated:

- 1) Improved understanding of the mechanisms that link biodiversity change and risks of infectious disease;
- 2) Identification of the anthropogenic or social factors that affect biodiversity loss;
- 3) Use of monitoring and predictive tools to reduce the incidence of human infectious diseases;
- 4) Improved strategies and communication that can encourage changes in human behavior to help reduce biodiversity loss and to decrease exposure to disease risks;
- 5) Improved analysis of land-use planning that considers environmental and human health impacts.

CONCLUSION

The Millennium Ecosystem Assessment (MA) revealed a need to understand the relationship between biodiversity and ecosystem functioning as well as the consequences of

biodiversity loss (Carpenter et al., 2006). In response to the research priorities identified by the MA and the growing ecological health community, the U.S. EPA is embarking on a new interdisciplinary research program to encourage novel approaches to test hypotheses examining the links between anthropogenic stressors, biodiversity, and human health. Characterizing this relationship can reveal general principles and models that are transferable across health issues and spatial scales.

Infectious disease is one important aspect of this agenda. Future efforts should include research and policies that examine the role of wetlands in protecting coastal areas, the control of invasive species, threats to food production, and other issues that intersect biodiversity, health, and well-being. By uniting the disciplines of conservation biology, ecology, epidemiology, and the social sciences, we can work toward a common agenda of restoring ecosystem health and improving human health and well-being. The impending crisis of biodiversity loss and potential adverse effects of climate change should compel researchers to cross the great disciplinary divide.

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