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COMMENTARY

Building Bridges: Connecting the Health and Conservation Professions

Sharon L. Deem[1,2,3,4], **Patricia G. Parker**[1,3], and **R. Eric Miller**[1]

[1]WildCare Institute, Saint Louis Zoo, One Government Drive, Saint Louis, Missouri, 63110, U.S.A.

[2]Charles Darwin Foundation, Puerto Ayora, Santa Cruz, Galápagos, Ecuador

[3]Department of Biology, University of Missouri - St. Louis, 8001 Natural Bridge Road, Saint Louis, Missouri 63121, U.S.A.

THE CHALLENGES THAT HINDER OUR ABILITY TO CONSERVE TROPICAL ECOSYSTEMS escalate daily with each tree felled, road built deeper into the forest, and additional human to feed, shelter and clothe, with ever dwindling natural resources. Biologists working in the field of tropical conservation are familiar with the increasingly complex and pervasive anthropogenic changes, negatively impacting the world, and challenging conservation efforts. These human-induced changes may be categorized as: (1) environmental and ecological; (2) shifts in human demography; (3) increased global travel and trade; and (4) technological and agricultural practices; and each can limit or even nullify biodiversity conservation efforts due to their direct and indirect impacts on the health of animals, humans, and ecosystems (Daszak *et al.* 2000, Deem *et al.* 2001, 2008, Jones *et al.* 2008, Lafferty 2008). In this commentary, we present a historical view of disease within tropical conservation efforts, current impacts of diseases on conservation initiatives, and, using our partnership as an example, provide a solid agenda for building bridges between the health and conservation professions so that we can more effectively perform tropical conservation.

It is useful to first define 'health' and 'disease' in the context of our commentary since these are broad terms that often mean very different things depending on one's discipline and world view. The World Health Organization defines health as a state of complete physical, mental, and social well being and not merely the absence of disease or infirmity (Last 1983). While this state can serve as a laudable goal, it does not provide us with objective criteria for determining the health of wildlife or ecosystems. In wildlife, disease can be defined as any compromised (unhealthy) state in which an individual is unable to perform its ecological roles in an ecosystem, due to either an infectious (*e.g.*, viral, bacterial, fungal, parasitic) or noninfectious (*e.g.*, toxins, trauma) etiology. Much as it is easier to define disease, as opposed to health, in wildlife it remains difficult to define a healthy ecosystem. However, assessing the health of an ecosystem can be approached by one of three methods: (1) ecosystem distress syndrome; (2) counteractive capacity; and (3) risk analysis (Rapport 1995). With each of these methods, various indicators of stress (disease) and/or ecosystem responses are measured allowing an objective evaluation of the state (health) of a particular ecosystem. In summary, the health of an individual, population, or ecosystem might best be considered its ability to efficiently respond to challenges (diseases) and effectively restore and sustain a 'state of balance'. In fact, one way to view the core objective of any conservation program is the intention to ensure healthy wildlife populations and ecosystems, without compromising the health of humans. In turn, the health of these three components; wildlife, ecosystems, and humans are increasingly dependent on conservation management measures.

Oddly, some conservationists still hesitate to put health studies into the conservation equation, questioning whether disease influences their focal populations. This reluctance seems an anachronism at a time when the negative impacts of diseases on biodiversity are becoming increasingly evident. Some may feel that any form of health intervention is not justified and we must maintain a 'hands-off' approach when considering preventive measures and health-related solutions. This reluctance is also irresponsible since today there remain few species that have not been influenced by some form of human intervention, primarily in a negative way (Vitousek *et al.* 1997).

There are many examples of disease-related population declines and extirpations in wild populations of plant and animals, as well as an increasing number of species' extinctions related to disease. Diseases have ecological impacts on multiple scales, affecting individuals (survival, reproduction), populations (population size, gene flow), communities (shifts in dominant or abundant species, changes in species composition), and ecosystems (changes in ecosystem structure, function, and resilience) (Deem *et al.* 2008). In recent years, emerging infectious diseases (EIDs)—diseases that have appeared in a population for the first time or that had been known previously but are rapidly increasing in incidence or geographic range—have been shown to negatively impact biodiversity and endangered species conservation. These EIDs include chytridiomycosis in amphibians, fibropapillomatosis in sea turtles, canine distemper virus in a number of terrestrial and marine carnivores, chestnut blight in chestnuts, as well as H5N1 avian influenza, Ebola virus and SARS in humans and animals (as reviewed in Daszak *et al.*

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[4]Corresponding author; e-mail: deem@stlzoo.org

2000, Deem *et al.* 2001, Anderson *et al.* 2004, Kuiken *et al.* 2005). Today, EIDs are a priority concern for biodiversity conservation, public health, and international security.

Often not as well quantified are the noninfectious diseases associated with anthropogenic changes. These too are having increased impacts on health, as best exemplified by toxin-related cancers, immuno-suppression and endocrine disruption (Colborn *et al.* 1996) in animals, plants, and humans, now appearing in some of the most pristine areas on the Earth. And, even though noninfectious diseases may appear more subtle than infectious disease-caused morbidity and mortality, these diseases can have profound impacts on biodiversity conservation.

As an appreciation for the impact of diseases on our study populations grows, bridges (partnerships) between the health and conservation professions are also developing (for examples see Deem *et al.* 2000, Daszak *et al.* 2004, Parker *et al.* 2006). Although still limited in number, these partnerships are designed to put health issues within the broader context of conservation. One model example of this joining of the conservation and health professions is the partnership between behavioral, population, and veterinary scientists, working on the avifauna of the Galápagos Islands (Parker *et al.* 2006). Through this partnership an extensive body of data has been amassed on avian health issues; much of these data have led to conservation actions in consultation with the Galápagos National Park.

Now in its seventh year, this Galápagos avifauna health and conservation partnership has utilized many principles of conservation biology, including population surveillance, training of young conservationists, public education and awareness, and policy recommendations for effective management practices based on sound scientific investigations (Parker *et al.* 2006). All these principles have been played out within a collaborative effort including scientists from the health (*e.g.*, pathologists, wildlife veterinarians, epidemiologists) and conservation (*e.g.*, geneticists, ecologists, conservation biologists, zoologists) fields. A number of the health discoveries made through this partnership have supported our hypothesis that diseases currently threaten avian conservation in the archipelago.

Two of our projects clearly exemplify how this partnership has provided solid data for conservation management. We have described a newly identified microfilaria of Galápagos penguins (*Spheniscus mendiculus*) and flightless cormorants (*Phalacrocorax harrisi*); with an overall prevalence of 42 percent in cormorants and 14 percent in penguins (Merkel *et al.* 2007). Although the impact of this parasite on the fitness cost and health of these two endangered species is unclear, our population ecology studies have shed light on possible disease transmission dynamics for this and other pathogens. Our data show that flightless cormorants have high genetic divergence between populations with the ocean serving as a dispersal barrier for the species (C. V. Duffie, T. C. Glenn, F.H. Vargas, and P. G. Parker, unpubl. data). In contrast, we found that the penguins are effectively a panmictic population, mixing regularly among the four island populations (Nims *et al.* 2008). Thus, we surmise the penguins are most likely responsible for the movements of this microfilaria within both the penguin and cormorant populations and more importantly, any introduced disease agent into one of the penguin populations (*e.g.*, *Plasmodium relictum* or West Nile virus) could result in widespread dissemination throughout the entire Galápagos flightless cormorant and penguin populations, thus warranting continued health monitoring (Travis *et al.* 2006).

In a second project on the endemic Galapagos hawk (*Buteo galapagoensis*) we have shown that the archipelago-wide population is genetically inbred and highly divergent between the different island populations (Bollmer *et al.* 2005). This finding provided instrumental data and gave direction for a further study in which we demonstrated that there is a phylogeographic influence on the health status of the endemic Galápagos hawk with populations on smaller islands having decreased immunologic status and higher parasite loads (Whiteman *et al.* 2006). To our knowledge, this is the first study linking inbreeding, innate immunity, and parasite load in an endemic, *in situ* wildlife population and it provided a clear framework for the assessment of disease risks in a Galápagos endemic. Based on these risks we made recommendations to the Galápagos National Park to limit tourist visitations to the smaller uninhabited islands that have Galápagos hawk populations (and perhaps other species as well) more susceptible to introduced pathogens.

Lastly, data from a few of our numerous other studies include the documentation of avian disease pathogens present in the rapidly expanding domestic poultry industry on the islands (Gottdenker *et al.* 2005, Soos *et al.* in press) and the establishment of *Culex quinquefasciatus* (a mosquito that can transmit avian malaria and West Nile Virus) (Whiteman *et al.* 2005). These two examples were instrumental in our conservation management recommendations to increase bio-security measures on poultry farms and vector control.

By partnering scientists from the health and conservation professions, the discoveries above (and a number of others) were possible due to the combined knowledge base and experience of the various partners, each bringing a unique and valuable perspective and skill. But this does not mean that the partnership arose naturally; in our case, a fortuitous combination of circumstances led to its origin. The population biology arm of the collaboration was already working in the islands, when the local institutions publicly declared their concern over the arrival of new diseases, having witnessed many disease-related extinctions in the Hawaiian endemic avifauna. The population biologist had accepted a joint appointment at the Zoo and the university/Zoo partnership expressed their interest to the local Galápagos institutions (the Park headquarters and the resident international scientific advisory group) in working with them on the problem, and a four-way partnership was constructed. We believe that one key to success of this collaboration has been the continuous attention paid to the involvement and satisfaction of each partner institution. Constant communication has been vital to assure that each partner feels 'ownership' in their portion of the program. We recognize that the value systems of universities, zoos, national park headquarters, and scientific advisory groups may differ, and thus our collaboration was structured in a manner that maximized the currency of value accruing to each partner, while minimizing competition among them. The University has taken the lead on many publications, the currency of greatest value to academics; the Zoo's involvement in a proactive conservation effort in an iconic location gives them the visibility that they value as zoos

TABLE 1. *Concrete actions necessary to build bridges between the conservation and health professions.*

Actions	Examples	Future directions
Curricular changes in veterinary (to include ecology) and conservation (to include disease) programs	Growing number of Universities that offer courses that cover the basics of both (Mazet *et al.* 2006; http://welcome.warnercnr.colostate.edu/)	Continue to increase the cross-over education of all disciplines within the conservation and health professions
Joint meetings that merge these professions	There are an increased number of conservation biology programs in wildlife veterinary meetings and disease programs in traditional conservation meetings	Continue to foster this merging of professionals across traditional health and conservation lines
International conferences specifically focused on understanding disease ecology as it relates to conservation efforts	Hudson *et al.* 2002, Collinge & Ray 2006, Ostfeld *et al.* 2008	Continue to hold these conferences that bring together the health and conservation professions
Joint appointments across the traditional departments of veterinary medicine and conservation biology	Increasing number of plant and animal pathologists and epidemiologist hired in conservation biology departments	Veterinary schools must increase courses in ecology and have biologists/ecologists on staff
Partnerships to bridge the professions	Examples include Deem *et al.* 2000, Daszak *et al.* 2004, Parker *et al.* 2006	Advance these partnerships among all conservation organizations and professionals
Field studies conducted and conservation management efforts that incorporate disease and health into the larger, all embracing conservation program	Moving beyond the conference and meeting level, to bring the professions together *in situ*, as well exemplified in this commentary	Use of multidisciplinary teams at your field site and within your conservation program
Journals to bridge the professions	Animal Conservation, EcoHealth, Ecology and Society, and many others	Submit papers to these journals and read papers that might not be in your discipline but will educate all so that we can be conservation biologists without boundaries

expand their conservation mission from *ex situ* efforts to include field studies; the Galápagos National Park gets the information as quickly as possible, and management recommendations based on this information for their consideration; and the scientific advisory agency manages the logistics of on-site activities, showing their ability to sustain and manage an important science advisory activity. Importantly, every partner is proud of their role and each partner is essential. And of course all four institutions receive all rewards: publication credentials, visibility, and information critical for the effective management.

During the years of this partnership, our work, which also includes a number of genetic and ecological studies, has shifted to a greater emphasis on health issues as the disease impacts on Galápagos avifauna became increasingly evident ('look and you shall find') to members of the partnership. As the Galápagos Islands represent a microcosm of the larger tropical world, this partnership between the health and conservation professions is an appropriate example of the important and necessary bridges we must build for tropical conservation. And, although island systems differ from continents in a few key ecological processes, anthropogenic changes (an increase in human population, travel and trade within the bounds of limited resources) are occurring in all tropical ecosystems, impacting the health of wild lands and wildlife throughout the tropics.

In today's world, with increasing human-induced changes on the wildlife and ecosystems, and the increased incidence of disease-related morbidity and mortality among the species we wish to conserve, we believe it most appropriate to ensure proper conservation management measures are implemented based on sound science and an appreciation of the population biology, ecology, and health issues of concern. Only then will we be able to prevent and control the diseases that may otherwise offset our conservation efforts. However, as is true for all conservation management measures, we must determine what the level of health-related involvement and intervention should be within any conservation project. This involvement might be based on: (1) the status of the species or population affected or at risk; (2) the nature of the cause of the health problem; (3) the spatial distribution of the species; (4) the cost and practicality of the necessary preventive or treatment measures; (5) specific disease issues of concern; and (6) implications of intervention or lack thereof on the health of other species, including humans and domestic animals (Deem *et al.* 2001).

To be proactive and properly address the six points above, we must unite the health and conservation professions. In Table 1 we offer concrete actions that will move us forward as we forge these bridges. Only through such actions will we be better able to understand the extent to which diseases hinder our conservation efforts, and to determine the conservation measures needed to prevent and control these diseases. In fact, it is rather arbitrary to divide the health and conservation professions, as members of the health field are often conservationists who possess a specialty (*e.g.*, veterinarian, epidemiologist, plant pathologist) similar to conservation professionals that might be trained as geneticists, ecologists, or botanists. Although roadblocks continue to slow the construction of these bridges, including semantic barriers (such as how one defines health) and different world views between the disciplines, the foundations are there, and a few examples exist today, serving as blueprints. Now we must build a network of bridges, so that the 'health' perspective is fully involved in conservation efforts. These bridges are imperative if we are to adequately address the increasing number of disease threats to biodiversity conservation in the tropics and elsewhere on our fragile planet.

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