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Moving Beyond Too Little, Too Late: Managing Emerging Infectious Diseases in Wild Populations Requires International Policy and Partnerships

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Emerging infectious diseases (EIDs) are on the rise due to multiple factors, including human facilitated movement of pathogens, broad-scale landscape changes, and perturbations to ecological systems (Jones et al. 2008; Fisher et al. 2012). Epidemics in wildlife are problematic because they can lead to pathogen spillover to new host organisms, erode biodiversity and threaten ecosystems that sustain human societies (Fisher et al. 2012; Kilpatrick 2011). There have been recent calls for large-scale research approaches to combat the threats EIDs pose to wildlife (Sleeman 2013). While it is true that developing new analytical models, diagnostic assays and molecular tools will significantly advance our abilities to respond to disease threats, we also propose that addressing difficult problems in EIDs will

require considerable shifts in international health policy and infrastructure. While there are currently international organizations responsible for rapidly initiating and coordinating preventative measures to control infectious diseases in human, livestock, and arable systems, there are few comparable institutions that have the authority to implement transnational responses to EIDs in wildlife. This absence of well-developed infrastructure hampers the rapid responses necessary to mitigate international spread of EIDs.

The impacts of infectious diseases in wild populations are not restricted to wild animals and plants; they also threaten public health (e.g., West Nile virus; Kilpatrick 2011), livestock (e.g., badger tuberculosis; Gallagher and Clifton-Hadley 2000), and food and crop safety (e.g., wheat rust and cotton wilt; Burdon and Thrall 2008). However, concerted research and disease management initiatives

rarely target diseases such as these unless they infect humans, livestock, or crops. They almost never focus on the wild populations where EIDs often originate (Jones et al. 2008). Therefore, the root of the problem can remain largely neglected, and pathogen spread often becomes too extensive for control efforts to be effective. Furthermore, the loss of biodiversity due to EIDs creates a suite of new challenges that we are just beginning to recognize as we gain an understanding of the ecosystem services that wild populations provide (Fisher et al. 2012).

Two recent EIDs illustrate both our recent progress in recognizing the early warning signs of disease in wild populations and the challenges associated with responding effectively to that knowledge: amphibian chytridiomycosis and bat white-nose syndrome.

Pronounced population declines and even extinctions in amphibians were first discussed in the late 1980s (Fig. 1). However, the pathogen (*Batrachochytrium dendrobatidis*) that causes chytridiomycosis was not identified until a decade later (Berger et al. 1998). Management plans for this pathogen were finally developed in 2006 in Australia and in 2007 in the United States (Collins and Crump 2009). By then, however, lineages of the pathogen had spread across wide geographic areas (Fisher et al. 2012), contributing to losses of amphibian biodiversity that exceed historical extinction rates by at least 200 times (McCallum 2007). Chytridiomycosis is now considered to be one of the most

devastating vertebrate diseases in recorded history (Fisher et al. 2012; Collins and Crump 2009).

More recently, the occurrence of white-nose syndrome (WNS) in bats provides a powerful example of how a new appreciation for wildlife diseases (e.g., insights gained from chytridiomycosis) informed a strategic response to an epidemic in a wild system. Mass mortality of bats was first noticed in 2007 (Fig. 1). Less than two years later, the fungal pathogen [*Pseudogymnoascus* (formerly *Geomyces*) *destructans* (Minnis and Linder 2013)] was described and management actions were implemented soon thereafter (Blehert et al. 2009; Lorch et al. 2011; US Fish and Wildlife Service 2011).

While the response time was far still slower than for many disease outbreaks in humans, the improved timeline for recognizing and addressing WNS can be attributed to coordinated pre-disease population monitoring, technological advancements in diagnostic tools, and importantly, a heightened appreciation that disease can cause precipitous declines and even extinction among wildlife species. In particular, the US Fish and Wildlife Service (USFWS) assumed an important role in facilitating communication among researchers and wildlife managers. USFWS involvement was partly due to the fact that some WNS-affected bat species were already listed as “Endangered” under the US Endangered Species Act. In contrast, a coordinated response in Canada, where there is no federal protection of affected species, was slower despite similar levels of disease-related

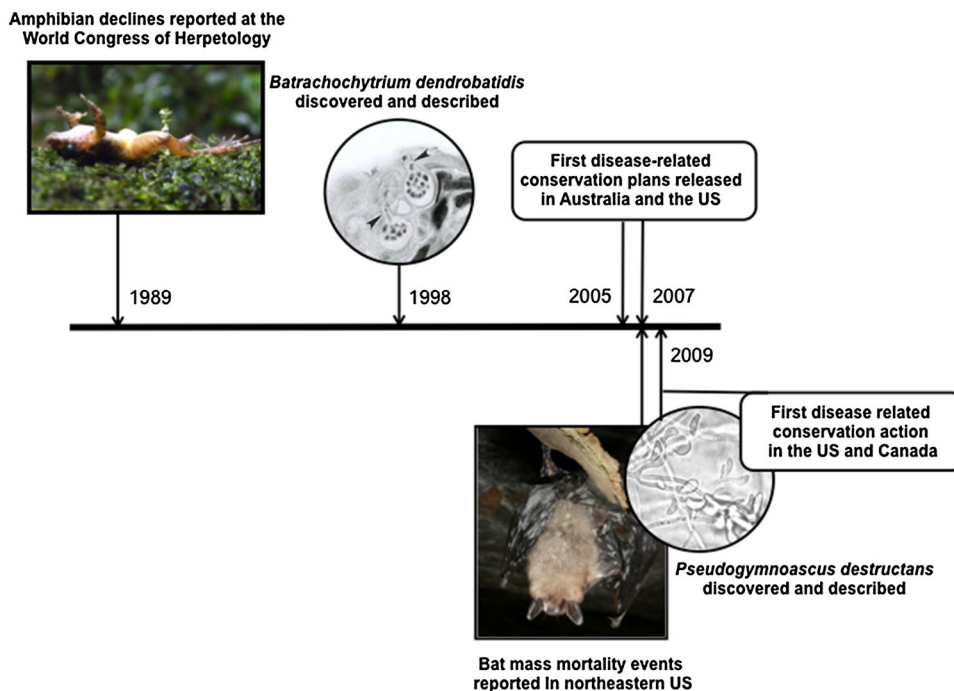


Figure 1. Timeline of infectious disease emergence and responses in wild populations. Unprecedented amphibian declines were reported in the 1980s, but the disease chytridiomycosis was not described until 1998, and action plans were not available until 2005 and 2007 (Berger et al. 1998; Collins and Crump 2009). Bat die-offs were noticed in 2007, the pathogen was described in 2009, and conservation actions were implemented in 2010 (Blehert et al. 2009; Frick et al. 2010; US Fish and Wildlife Service 2011).

mortality. Currently, trends predict decline and possible extinction of multiple bat species, which creates complex and costly problems, including listing multiple bat species on endangered species lists (Frick et al. 2010).

The loss of wild populations to EIDs and increased risks for public health need not be a foregone conclusion as rapid response models already exist. For example, in 2003, an *ad hoc* association of academic and health-care providers correctly recognized the epidemic potential of a novel respiratory pathogen of humans in Hong Kong called Severe Acute Respiratory Syndrome, SARS (Heymann 2004). The World Health Organization (WHO) helped coordinate an international effort to: (1) characterize the pathogen; (2) optimize diagnostic tests; and (3) generate appropriate action plans to reduce contact rates (Heymann 2004). Ultimately, these immediate actions almost certainly reduced pathogen transmission, which led to rapid declines in infection rates during the nine-month duration of the epidemic (Heymann 2004).

The international response to the SARS outbreak was highly successful and revealed the need for, and efficacy of, (1) an effective reporting system and (2) rapid coordinated responses to newly emerging diseases. This model was subsequently adopted in a revision of the International Health Regulations (WHO IHR 2005). Currently, the WHO continuously sifts through incoming epidemiological information, triages case studies and pathogen identification, and determines the most appropriate advice to pass along to international (e.g., *Medecin Sans Frontiers*, International Red Cross) and national-level public health providers.

The comparable organizations that address animal health issues currently have limitations that prevent rapid and effective responses in wild populations. Although many countries have frameworks to address animal health at regional or national scales, they tend to be globally disconnected. For example, in response to the dramatic declines of bat species due to white-nose syndrome, the US House of Representatives recently introduced legislation that would allow the Secretary of Interior to identify and declare wildlife disease emergencies, establish an emergency fund for rapid response actions, and outline the membership composition of a “Wildlife Disease Committee” that will be responsible for coordinating action among government agencies (Wildlife Disease Emergency Act of 2014). These are laudable objectives that would significantly facilitate rapid responses to wildlife EIDs within the US borders. It is unclear, however, if the legislation would be as instrumental in the event that an infectious wildlife disease spreads to neighboring countries.

For international organizations that focus on animal health, some advocate pathogen surveillance and encourage reporting of emerging infectious diseases, but lack effective ways to guide and coordinate international research, intervention, and management actions. The World Organization for Animal Health (Office International des Epizooties, OIE), a leading organization for animal health, has a working group to address infectious diseases in wildlife and recently created a reporting system (WAHIS-Wild 2014). The newly developed interface was established for reporting on non-OIE (non-listed) wildlife infectious diseases and has the potential to be an excellent advancement (http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home). However, responding to the incoming information (e.g., guiding and coordinating international research, intervention, and management actions) is a considerable challenge. For example, the OIE recognized *Bd* as a notifiable pathogen in 2008, one of the first organisms listed for their threat to global biodiversity (WHO Aquatic Animal Health Code 2008; Schloegel et al. 2010), but regulations for reporting pathogen detection only apply to member countries, and there are no international protocols for responding to outbreaks of chytridiomycosis. Thus, the OIE mechanisms for international cooperation for action on wildlife diseases could be further expanded, developed and more effectively harnessed to respond to disease-related threats to biodiversity.

The rapid and data-driven response system for human disease provides a model of successful intervention that could be applied to wild systems to conserve biodiversity and protect public health, agriculture, and ecosystems. Formation of an international network or further developing cross-agency collaborations to facilitate rapid responses would serve to integrate incoming epidemiological information to implement rapid, science-based responses when EIDs are recognized in wild systems (Rubin et al. 2014). A transnational system would (1) integrate currently disparate disease surveillance programs across countries; (2) offer a forum to facilitate communication among experts in wildlife and disease systems, including veterinary and plant pathologists, ecologists, epidemiologists, wildlife managers, academic and government researchers, and others; (3) provide reference points for emergency response while creating guidelines for management actions during and after EID outbreaks; and (4) coordinate education and public outreach efforts such that public information is available from a central location. A stable infrastructure would eliminate the need to develop response structures *de*

novo for each new pathogen and allow for more rapid, efficient, and coordinated responses to infectious disease emergence in wild systems.

Fostering communication on emerging infectious diseases in wild populations is an important first step. Increasingly sophisticated informatics-based epidemiological tools (e.g., ProMed, HealthMap and the OIE's World Animal Health Information System, WAHIS) can detect and disseminate infectious disease alerts and could be effective tools for determining anomalous patterns of infectious diseases in wild populations. Similarly, baseline information on population numbers and levels of biodiversity (e.g., IUCN Red List, National Ecological Observatory Network, Global Earth Observing System of Systems) constitute key resources for detecting declines in wild populations. These currently disparate groups are in a position to act as partners in developing an expanded global network and reporting system for disease outbreaks. Establishing forums for discussion (e.g. using online platforms and in-person conferences) will be critical for addressing EIDs that warrant immediate action.

Just as the need for coordinated international responses to human diseases stimulated development of the WHO and International Health Regulations, so too would an equivalent structure facilitate effective responses to EIDs in wildlife. Steps to integrate and improve existing programs and formalize a system for responding to EIDs in wild populations would not only be beneficial for wildlife but are also important for maintaining the health of humans and livestock. As in the management of all EIDs, rapid action will require acting on imperfect information, and responses to diseases in wild populations are likely to present unique challenges (Morens et al. 2004). However, by emulating other emergency response models, we can lay the groundwork for high priority actions. An optimal management strategy can be reevaluated and revised after appropriate measures have been taken to protect public health, safeguard against species extinction and ensure ecosystem functioning. Establishing a transnational network and response system for EIDs in wildlife will improve our responses that currently come "too little, too late."

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