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Conservation Medicine:

Tackling the Root Causes of Emerging Infectious Diseases and Seeking Practical Solutions

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West Nile virus was first detected in North America in the summer of 1999, in New York City, when a dead crow with the disease was found at the Bronx Zoo. Within three months, WNV had spread to Connecticut and New Jersey, killing tens of thousands of birds, and it has continued to spread across the continent.

Because of their vulnerability to environmental change, amphibians are often viewed as good indicators of environmental health, revealing the initial effects of environmental degradation. Over the past 50 years, frog populations have experienced die-offs and declines globally. Some of the drops in frog populations can be attributed to deforestation, others to the draining of wetlands, and still others to the effects of pollution. In the late 1980s, however, scientists began to notice increasingly significant population declines and extinctions in amphibians inhabiting relatively pristine habitats. Researchers later discovered that these events coincided with outbreaks of a previously unknown disease, chytridiomycosis, which is caused by a fungal pathogen, *Batrachochytrium dendrobatidis.*[1] This disease has been implicated, for example, as the proximate cause of extinction of the golden toad of Costa Rica (*Bufo periglenes*) and two species of Australian gastric brooding frogs (*Rheobatrachus silus* and *R. vitellinus*).

In Australia, Indonesia, and Papua New Guinea, individuals of the green tree frog species have been found to be sick with the chytrid fungus, a previously unknown disease. Outbreaks of the disease have coincided with increasingly significant population declines and extinctions in amphibians inhabiting relatively pristine habitats.

Nobody knows with certainty when, where, and why this pathogen first emerged. Most likely the disease has existed in some amphibian populations for many years until recent habitat alterations (e.g., habitat fragmentation, species introductions, climate change, etc.) led to opportunistic infections of new hosts. Another theory suggests that the pathogen piggy-backed on the international trade in wildlife as food and pets across international boundaries, allowing the fungus to spread to naïve populations. Recent studies have shown that the bullfrog (*Rana catesbiana*), which is transported interna-

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There have been no recorded cases of transmission of brucellosis—a disease originally transmitted to bison from livestock—from wild bison back into livestock; however, the perceived risk has led to conservation concerns for bison.

tionally for both the food and wildlife pet trades, has all the characteristics of a carrier of this disease: It is capable of being infected with the pathogen but suffers only minimal effects itself.

Deforestation, species introductions, chemical pollution, globalization, and climate change—all of these human-induced ecosystem alterations threaten the survival of wildlife populations. But when such ecosystem alterations also result in pathogen pollution (the movement of pathogens or hosts to new locations), additional ecological disturbance can occur due to the potentially devastating impacts on wildlife health.

Emerging Infectious Diseases

Emerging infectious diseases (EIDs) are diseases that have recently increased in prevalence or geographic range, have moved into new host populations, have been recently discovered, or are caused by newly evolved pathogens. The seriousness of this threat to wildlife, as well as to humans, has been made apparent by the recent emergence of Severe Acute Respiratory Syndrome (SARS), monkey pox, West Nile virus (WNV), and other diseases. As humans venture into previously undisturbed habitats, cut down forests, transport wildlife, and travel across great distances, this threat is amplified. The result is an alarming number of newly discovered EIDs, some causing human mortality on a global scale (e.g., HIV/AIDS, drug resistant tuberculosis), and others emerging locally (e.g., Ebola, Hantavirus) without known therapies, cures, or vaccines.

Despite enormous interest in EIDs that directly affect people, scientists have only recently begun to show that wildlife also suffers from EIDs. This follows a number of high profile outbreaks of wildlife diseases—such as amphibian chytridiomycosis—causing population declines or even contributing to extinctions. In January 1996, the last individual of a Polynesian tree snail *(Partula turgida)* died in a lab in the London Zoo. Once an inhabitant of the Society Islands, this species began to decline after a predatory snail (*Euglandina rosea*) was introduced for biocontrol purposes. Pathological examinations of the last individuals, however, revealed that death of the last population was the result of infection by a microspor-idian parasite (*Steinhausia sp.*).

Increased intensification of pig farming adjacent to fruit bat colonies, along with other human-caused factors, may have contributed to the emergence of Nipah virus.

To date, the loss of *P. turgida* is the only proven case of extinction by infection (albeit in captivity); however, EIDs are suspected in a number of other extinctions. For example, although introduced pathogens are thought to be the proximate cause of the extinctions of many of the original endemic Hawaiian birds and some other species, definitive proof has not been, and may never be, obtained. Establishing such proof may continue to prove elusive, because it requires data on population biology, as well as on the health and pathology of at least one individual of the last remnant group. Some evidence suggests that chytridiomycosis led to the extinction of the sharp-snouted day frog (*Taudactylus acutirostris*) in Australia. Analysis of one of the last known individuals of this species revealed infection by the chytrid fungus. In 2001, the status of the sharp-snouted day frog was assessed and subsequently listed as critically endangered on the IUCN (World Conservation Union) Red List of Threatened Species. This assessment is conservative; its status is likely to change to extinct within the next ten years.

Potential Causes of Pathogen Emergence and Spread

Approximately 75% of emerging human diseases are zoonoses, meaning that they are infectious to both humans and animals. In particular, zoonotic EID pathogens often emerge when they spread from an animal reservoir—in which pathogens live and multiply but rarely or never result in illness or mortality—to another host that is susceptible to the disease. This makes it difficult to predict which wildlife pathogens will emerge next. In some cases, pathogens move from wildlife to humans, and then evolve to become serious global infections—such as HIV/AIDs. In almost all cases, the emergence of these zoonoses is a result of human-mediated alterations to natural ecosystem processes.

Understanding EIDs requires an understanding of the environmental changes that cause them to emerge and spread—changes in human behavior; travel of humans, wildlife, and domestic livestock around the

Research has shown that the disappearance of African wild dogs from the Serengeti that occurred in 1991 was caused by the transference of canine distemper and rabies in domestic dogs of that area to wild dogs.

world; agriculture and livestock production; and encroachment of human communities into wildlife habitat. The causal pathway by which these environmental changes may affect wildlife health, human health, and aspects of disease ecology (e.g., species extinctions and increased transmission of pathogens to humans) is under current investigation, but case studies can illustrate the close correlation between human-induced ecosystem changes and disease emergence.

Live Animal Markets and SARS

The recent outbreak of SARS has been traced back to markets that deal in diverse wild mammals, birds, and reptiles for food. Molecular evidence suggests that masked palm civets ("civet cats") present at these markets were infected by the virus that caused SARS in humans, although many experts believe there may be an additional wildlife reservoir. Locating that reservoir could give scientists insight into the reasons behind the emergence of this disease and could have important implications for preventing future outbreaks.

Nipah Virus: At the Interface Between Farming and Wildlife Habitat

Nineteen ninety-eight marked the emergence of the Nipah virus in Malaysia. This lethal virus, first identified in pigs and pig farmers, killed 100 people in a single outbreak and led the Malaysian government to cull 1.1 million pigs in an effort to stop the epidemic. Researchers later discovered that fruit bats are the reservoirs for this disease.[2] The virus was transmitted from infected fruit bats to pigs, which acted as "amplifier" hosts for the disease, increasing the transmission and prevalence of the virus. Infected pigs developed a barking cough, at which time the virus became an airborne pathogen that was then transmitted to humans. The emergence of Nipah virus may have been triggered by any number of anthropogenic or other changes, such as human encroachment into fruit bat habitat (i.e., intensification of pig farming adjacent to fruit bat colonies), climatic factors, forest fires and drought, or land-use change.

Climate Change

Recent research indicates that global climate change may be another contributing factor in the emergence and/or movement of diseases. Climate-induced changes in temperature, rainfall, and humidity may alter the dynamics of host-pathogen ecology for many emerging diseases. For example, increased water temperature can have negative consequences for two species of commensal chaetogasters inhabiting the mantles of aquatic snails. Research has shown that these commensals act as predators, attacking and ingesting the infective stages of parasites attempting to infect a snail host. With an increase in temperature, the chaetogasters abandon the snail and die, resulting in an increase in the rate of parasitism on the snails.[3]

For vector-borne pathogens (i.e., those transmitted from one host to another via an insect or other animal) such as dengue, malaria, Lyme disease, and West Nile virus, temperature increases may increase the development rate of the pathogen, the number of generations per annum, and the pathogen's transmission rate; it may also enhance winter survival of pathogens or modify host susceptibility to infection. As northern latitudes warm, winter survival and the upward movement of carrier hosts or vectors (e.g., the northward movement of ticks carrying Lyme disease) may push EIDs into new regions.

It is important to note that, while climate change may lead to the emergence of pathogens, it could also lead to the *disappearance* of certain pathogens that normally play a role in regulating the size or density of host populations. In the absence of certain pathogens, the relative size of host populations can increase; this can result, for example, in greater predation on prey species or increased competition over resources with other species.

Pathogen Pollution and Globalization

Analyses suggest that pathogen pollution may account for 60 percent of the emerging diseases of wildlife. It has been linked to outbreaks of elephant herpes virus in zoos; crayfish plague in Europe; avian malaria and pox disease in Hawaii; and West Nile virus in North America. With the continuing globalization of trade in domestic animals and their products, wild animals and their parts (e.g., as pets, food, or for hunting), and contaminated produce and materials, pathogen pollution is likely to become an even more significant burden to human and animal health, environmental health, and the economy in the future.

For example, it is believed that West Nile virus reached North America in 1999, via infected international travelers. Whether the travelers responsible were of the human, avian, or mosquito variety is still unknown. It is clear, however, that the introduction of WNV to the Americas was most likely a result of human activity: the transport of infected humans, birds, or mosquitoes. Since the time of its introduction, WNV has swept across the country at an alarming rate, killing thousands of native birds. Researchers now fear that the virus will spread to the Hawaiian and Galapagos islands. If the virus reaches these remote

Courtesy Consortium for Conservation Medicine

A high diversity of species in small areas, such as at this live bird market in China, increases the opportunity for pathogen transmission.

areas, it could be devastating to the avian species inhabiting those islands, many of which are already at risk.

Spill-Over and Spill-Back

Domesticated animals (pets and livestock) and captive wildlife are often reservoirs for disease that can "spill-over" into free-roaming wildlife. Such events could be particularly devastating to endangered species. Small, isolated populations are more vulnerable to the effects of environmental stressors, including disease. For instance, since the 1960s, populations of the African wild dog (*Lycaon pictus*) have experienced significant declines and are now considered endangered. In 1991, wild dogs disappeared from the Serengeti, an event that coincided with outbreaks of canine distemper and rabies in domestic dogs in that area. Researchers have shown that the cause of the disappearance was outbreaks of these two diseases, which jumped to wild dogs from domestic dogs. The current focus of conservationists is to encourage widespread vaccination of pet dogs around wild dog habitat, and they are beginning to win the battle against this wildlife EID.

Of similar concern is the reverse of spill-over: spill-back. For example, brucellosis was most likely introduced into wild populations of bison in North America via domestic cattle in the early 1900s. Since that time, a national eradication program in the United States, along with an extensive vaccination program, has practically eliminated the threat of serious epidemics of brucellosis in cattle. The disease, however, still persists in some populations of bison, elk, and other wildlife. Ranchers now fear that the disease will be transmitted from the bison to livestock, making the livestock industry in certain states economically unviable. There have been no recorded cases of such transmission in the wild so far, but it is clear that the perceived risk is enough to cause serious conservation concerns for bison.[4]

Conservation Medicine

Our traditional definition of conservation entails the preservation or management of natural lands and their resident plants and animals to prevent exploitation, habitat loss, and species extinctions. Today, scientists are beginning to realize that this definition only scratches the surface of what conservation must become in the 21st century. The reality is that people are destroying ecosystems globally, and the shockwave this destruction creates threatens not only the habitat so vital for species survival and ecosystem integrity, but the *health* of *all* species: wildlife and plants, as well as humans and domestic animals.

A new field of study has emerged in response to the growing impact of human-induced environmental degradation on disease ecology. Conservation medicine is a multidisciplinary science dedicated to understanding how wildlife, human, and ecosystem health are related and to dealing with the threats that diseases pose to ecosystems. An ecological health collaborative, the Consortium for Conservation Medicine (CCM), was created to tackle the root causes of emerging diseases and the global spread of microbes. The CCM is a collaboration among Harvard Medical School's Center for Health and the Global Environment, Johns Hopkins Bloomberg School of Public Health, Tufts University's School of Veterinary Medicine, the USGS National Wildlife Health Center, and Wildlife Trust (not associated with The HSUS Wildlife Land Trust). It brings together key experts from the fields of veterinary medicine, public health, and conservation to form think-tank research groups that search for the causes of ecosystem-wide health problems and formulate practical solutions for a healthier planet.

The CCM and its partner institutions are involved in a variety of ongoing research projects. For example, the CCM is currently investigating the factors that led to the emergence of Nipah virus in Malaysia and a closely related virus, Hendra virus, which emerged in Australia. Additional CCM projects include a study on the dynamics of SARS in Asian wildlife, how human and environmental factors affect the prevalence and emergence of WNV, and ground-breaking research to aid in predicting how pathogen pollution might drive future emerging diseases.

Several recent, widely publicized EID outbreaks in humans and in wildlife populations around the world should serve as a wake-up call for public health experts, wildlife disease specialists, and conservationists. It is clear that diseases such as SARS, Nipah virus, and Ebola virus have the potential to cause widespread human suffering and death. However, our increasing awareness of the potential for the devastating effects these and other emerging diseases may have on sensitive wildlife populations must now inspire concentrated and coordinated research and action from multiple fields to inform and

Examples of Emerging Infectious Diseases and Their Effects on Wildlife, Ecosystems, and Human Health[5]

Disease and/or Pathogen	Effects	Emergence and/or Spread
BRUCELLOSIS Caused by any of several strains of the bacterium, *Brucella*. The strain found in bison and cattle in the United States is *Brucella abortus*.	**Wildlife Health:** Many wild mammals worldwide are susceptible to brucellosis, including ungulates. Brucellosis is usually not fatal in adult mammals but can cause reproductive dysfunctions such as spontaneous abortions. It is not clear whether brucellosis is adversely affecting the viability of infected wildlife populations. Attempts to eradicate the disease may have an impact on conservation that goes well beyond that of the disease itself.	*B. abortus* was most likely introduced to the United States with the importation of infected European cattle, which later came into contact with wildlife resulting in a "spill-over" event. Human exposures to brucellosis generally occur when people come into contact with tissues of infected livestock (e.g. at slaughterhouses or laboratories) or ingest unpasteurized dairy products from infected animals.
CHYTRIDIOMYCOSIS Caused by the fungus *Batrachochytrium dendrobatidis*.	**Wildlife Health:** Evidence suggests that chytridiomycosis caused the extinction of the sharp-snouted day frog in Australia and probably contributed to the extinction of the golden toad in Costa Rica and two species of gastric brooding frogs in Australia.	First identified in 1998, chytridiomycosis was associated with amphibian mass mortality events and population declines in Panama and Australia. The disease has since been reported in North America, South America, Africa, and Europe. International trade in wildlife, such as the bullfrog, may have contributed to the spread of this disease.
EBOLA HEMORRHAGIC FEVER Ebola is caused by infection with one of several strains of the Ebola virus, which belongs to the Filoviridae family of viruses.	**Human Health:** Ebola is often fatal in humans. The 2000–01 outbreak in Uganda sickened 425 people, more than 50% of whom died. The 2001–02 outbreak in Gabon and the Republic of the Congo sickened 122 people, nearly 80% of whom died. **Wildlife Health:** Often fatal in non-human primates, Ebola has contributed to the rapid decline of gorilla and chimpanzee populations in western Africa. A 2002 outbreak in the Rep. of the Congo resulted in the deaths of about 50% of the 1,200 gorillas found in a protected sanctuary between two infected villages. The regions most affected by Ebola are home to 80% of the world's remaining gorillas and most chimpanzees.	Ebola virus was first isolated in the Democratic Republic of the Congo. The Ebola virus is thought to have originated from the African continent. Though the natural reservoir of the disease is unknown, the first human infection in an outbreak probably follows human contact with an infected animal. Researchers are still looking for possible triggers—such as human encroachment into ape habitat—that may bring apes into greater contact with the virus.
MONKEYPOX Caused by the monkeypox virus, which belongs to the orthopoxvirus group of viruses.	**Human Health:** In the 2003 United States outbreak, 37 confirmed cases of monkeypox in humans in 6 states were reported. No human deaths were reported from the U.S. outbreak. In rural areas of central and west Africa, mortality ranges from 1% to 10%. **Wildlife Health:** Some scientists feared that infected pet prairie dogs might be released into the wild, potentially resulting in disease transmission to wild prairie dogs and other wildlife. To date, there are no reports that this has occurred.	Monkeypox was isolated for the first time in North America in 2003 when infected African rodents were shipped from Ghana to the United States to be sold as pets. Monkeypox was transmitted to North American prairie dogs—also captured for sale as pets—that were housed nearby. Human contact with infected prairie dogs appears to have been the primary route of transmission to humans.
NIPAH VIRUS ENCEPHALITIS A member of the Paramyxoviridae family.	**Human Health:** In the 1998–99 Malaysia outbreak, Nipah virus caused encephalitis in 265 people, killing 105. **Wildlife Health:** The initial outbreak of the virus led to the culling of 1.1 million pigs. Several species of fruit bats are known to carry the virus while exhibiting no adverse effects from infection.	Nipah virus was unrecognized until an outbreak from September 1998 to April 1999 in Malaysia. Encroachment of farming into fruit bat habitat may have triggered the outbreak. Fruit bats appear to have transmitted Nipah to domesticated pigs, which then transmitted the disease to humans.

Disease and/or Pathogen	Effects	Emergence and/or Spread
SEVERE ACUTE RESPIRATORY SYNDROME (SARS) Caused by a coronavirus, known as SARS-associated coronavirus.	**Human Health:** In the 2003 outbreak, SARS sickened 8,098 people worldwide and resulted in the deaths of 774 people. **Wildlife Health:** The Chinese government responded to the outbreak, in part, by ordering the killing of as many as 10,000 captive masked palm civets (or "civet cats"), despite uncertainty among health experts as to the need or effectiveness of this move. The direct effect of the virus itself upon civets or other wildlife is not yet known.	Wild animals, including masked palm civets, raccoon-dogs, and Chinese ferret badgers, held at live animal markets (for sale for human consumption) in southern China were found to have been exposed to SARS or a similar coronavirus. These live animal markets probably played a role in the transmission of SARS to humans.
WEST NILE VIRUS (WNV) Caused by a flavivirus closely related to St. Louis encephalitis.	**Human Health:** The CDC reports that WNV sickened 9,862 people in the United States and resulted in 264 human deaths in 2003. Infections in humans in the United States have been documented in 40 states and the District of Columbia. **Wildlife Health:** Infections in birds (225 wild and captive species to date) and other animals have been reported in 47 states, the District of Columbia, and Puerto Rico. Effects on bird populations are unknown at this time, but WNV may pose a significant risk to threatened and endangered bird species.	WNV was isolated for the first time in the United States (and in the Western Hemisphere) in Nassau County, New York, in August 1999. The virus is thought to have reached North America via infected international travelers (i.e. humans, birds, or mosquitoes). Researches now fear the virus may spread to the Hawaiian and Galapagos islands in the same way it reached the shores of North America.

drive public policy in the United States and abroad. Time is of the essence in responding to known disease threats and in preparing for the effects, on both human health and wildlife, of as yet undiscovered diseases that are certain to emerge in the near future.

Sources for Additional Information

Website of the Consortium for Conservation Medicine: *www.conservationmedicine.org.*

Selected Publications

EcoHealth: Conservation Medicine – Human Health – Ecosystem Sustainability

An international, peer-reviewed journal launched in 2004. The journal provides a timely forum for research, policy, and practice that integrates the ecological and health sciences. *EcoHealth* is the merger of the complementary journals *Ecosystem Health and Global Change and Human Health,* and a planned journal of the Consortium for Conservation Medicine. For more information, visit *www.ecohealth.net.*

Anderson, P.K., Cunningham, A.A., Patel, N.G., Morales, F.J., Epstein, P.R., and Daszak, P. "Emerging infectious diseases of plants: pathogen pollution, climate change, and agrotechnology drivers." *Trends in Ecology and Evolution* 119(10): 535-544.

Daszak, P., Cunningham, A.A., and Hyatt, A.D. 2001. "Anthropogenic environmental change and the emergence of infectious diseases in wildlife." *Acta Tropica* 78: 103-116.

Daszak, P., Cunningham, A.A., and Hyatt, A.D. 2000. "Emerging infectious diseases of wildlife: threats to biodiversity and human health." *Science* 287: 443-449.

Patz, J., Daszak, P., Tabor, G., Aguirre, A.A., Pearl, M., Epstein, J., Wolfe, N.D., Kilpatrick, A.M., Foufopoulos, J., Molyneux, D., Bradley, D.J., and Members of the Working Group on Land Use Change and Disease Emergence. 2004. "Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence." *Environmental Health Perspectives* 112(10): 1092.

Books

Aguirre, A.A., Ostfeld, R.S., Tabor, G.M., House, C., and Pearl, M.C. 2002. Conservation Medicine: Ecological Health in Practice. New York: Oxford University Press.

Pokras, M., Tabor, G., Pearl, M., Sherman, D., and Epstein, P. 1997. "Conservation Medicine: An Emerging Field." In Raven, P.H. (ed.), *Nature and Human Society: The Quest for a Sustainable World,* pp. 551-556. Washington, DC: National Academy Press.

Tabor, G.M., Ostfeld, R.S., Poss, M., Dobson, A.P., and Aguirre, A.A. 2001. "Conservation Biology and the Health Sciences." In Soulé, M.E. and Orians, G.H. (eds.), *Conservation Biology,* pp. 155-173. Washington, DC: Island Press.

(Endnotes)

[1] Berger, L., Speare, R., Daszak, P., et al. 1998. "Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America." *Proceedings of the National Academy of Sciences,* USA, 95: 9031 – 9036.

[2] Johara, M., Field, H., Rashdi, A., Morrissy, C., Van der Heide, B., Rota, P., Azri, A., White, J., Daniels, P., Jamaluddin, A., and Ksiazek, T. 2001. "Serological evidence of infection with Nipah virus in bats (order Chiroptera) in Peninsular Malaysia." *Emerging Infectious Diseases,* 7: 439 – 441.

[3] Sankurathi, C.S. and Holmes, J.C. 1976. "Effects of thermal effluents on parasites and commensals of Physa gyrina Say (Mollusca: Gastropoda) and their interactions at Lake Wabamun, Alberta." *Canadian Journal of Zoology,* 54: 1742.

[4] See Brister, D. 2003. "The Yellowstone buffalo slaughter." *Wildlife Tracks,* 6(1): 7 – 10.

[5] Sources for mortality statistics and other data: Centers for Disease Control and Prevention *(www.cdc.gov)*; World Health Organization *(http://www.who.int/en/)*; U.S. Geological Survey's National Wildlife Health Center *(http://www.nwhc.usgs.gov/)*; Wildlife Conservation Society *(www.wcs.org).*

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