Chapter 18
Bridging the Gap Between Conservation and Health

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Abstract Health is frequently in the news, whether it is the "bird flu" headlines or woven into the core of climate change reports. And in these articles, health is the common thread that connects humans, animals, and the environment; however, this underlying link is often undervalued, leaving a "gap" that challenges our ability to prevent and mitigate major global catastrophes. The Ebola virus disease has ravaged West Africa, leaving a swath of devastation and unanswered questions in its wake, but it highlights the alarming potential of a zoonotic disease, one of hundreds that pass between animals and humans. Climate change continues to fuel controversy, but it is undeniable that our exploitation of the Earth is impacting the fundamental resources that form the foundation of our existence. The state of our ecosystems is integral to the conservation and sustainable management of our wildlife and natural resources. The health of the environment cannot be segregated from our own health; thus, we need to examine health from a global stance. Our traditional perspectives of "health" and "disease" are outdated, and it is prime time for us to reevaluate our approaches to engage a comprehensive audience as well as holistic strategies to address these issues as "One Health."

18.1 Introduction

The genesis of this chapter originated from a meeting in Bangkok of the same title as this book, a forum where regional experts discussed and deliberated the vital minutia of individual human health and disease projects. The malaria researchers concluded that incidence and prevalence of the disease in humans could be reduced

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if there were no trees. While this may seem logical to human health experts examining the world through one end of a microscope, they need peer beyond the Petri dish: what would this world be like without trees? Herein lies the crux of our conundrum: the divide between health and conservation.

In a human-centered world, the term "health" unfailingly conjures images of disease and the human condition. However, this is merely one element in the broader definition of health that bridges humans, animals, and ecosystems. It is this "One Health" that binds our well-being to that of our surroundings in a complex, interdependent web upon which our existence is delicately, yet critically balanced. We must remember that health applies not only to individual organisms but to living systems as well: the intricate relationships between living organisms and the environment are often obscured, further challenging efforts to define and evaluate the state of ecosystems, their goods and services, as well as the dynamics of "One Health." Yet, the speed and scope of anthropogenic change and the lack of recognition of the long-term ecological impacts of our decisions only magnify this intense situation, creating an ever-evolving discord that tests the boundaries and resilience of the natural world.

Like the air that we breathe, humanity is part of the global environment that forms the basis for life on Earth. However, we, and our unabated population growth, have had an increasing hand in manipulating the state of the world and that of our future. Our influence over Earth's dynamics through the millennia has contributed to the degradation of ecosystems and the exploitation of natural resources, also referred to as "ecosystem goods and services." Ecosystems and their goods and services—food, air, water, nutrient cycling, for example—are the foundation for our health and well-being. These essential functions sustain human health and, in effect, life as we know it (MEA 2005). Even subtle shifts in ecosystem services can topple this fragile equilibrium and trigger social, economic, political, and demographic changes that potentially endanger our future. Thus, the ubiquitous, ever-expanding human footprint has fuelled unprecedented resource demands that have led to the urgent need to manage and conserve our natural capital in hope of a sustainable future. For example, we "consume" in one way or another as much as 40 % of all solar energy trapped by land plants (Erlich and Wilson 1991), a selfish action that not only threatens other species but that of our own (eds Grifo and Rosenthal 1997). Forests provide numerous ecosystem services that are fundamental to "health," including energy production, climate regulation, and nutrient cycling, but with the current rate of deforestation measured in acres per minute, our myopic actions defy logic, hence jeopardizing the future of this planet (Fig. 18.1).

Conservation and the sustainable management of our natural world have direct bearing on "health" in the broader context. In a concept that is simultaneously rudimentary and revolutionary, the "One Health" paradigm examines these challenges through a new multidisciplinary lens, addressing the issues through a consilience of human, animal, and ecosystem health, but this concept faces an uphill battle against tradition to gain traction. In June 2012, Rio + 20, the United Nations Conference on Sustainable Development, fell short on many fronts, but in its singular focus on economic development, failed to consider the social and environmental pillars that

Fig. 18.1 The "hard edge" between Bwindi Impenetrable National Park in Uganda and converted agricultural land (Photo: A. Yang)

are integral to sustainable development. Science-based evidence on global health issues were overshadowed by ideology and the final outcome "*The future we want*" omitted health as a cross-sectoral priority in sustainable development. Nevertheless, the general approach of this document allows for an unprecedented opportunity to engage health sectors, in all their incarnations, in the dialogue towards sustainable development goals (Langlois 2012).

18.2 Redefining Conservation

A general definition of conservation in this context is the act of preserving, protecting, managing, or restoring wildlife, habitats, and natural resources. Thousands of international and local conservation organizations and scores of professional scientists excel at quantifying conservation needs in order to objectively develop science-based strategies that counter present and future threats, with the goal of balancing man and nature. Conservation organizations, constrained by their areas of expertise and financial resources, focus on protecting species and habitats in a progressively anthropogenic arena. However, delineating national park boundaries and building fences to physically separate humans and wildlife animals is a less viable tool nowadays, particularly in developing countries where there is extensive interdependence between livelihoods and ecosystem services and where resource competition is fierce. Conservationists increasingly acknowledge that the root of many conservation issues stems from conflicts over space and resources and clashes with social or cultural beliefs, the underpinnings of which may fall outside of their sphere of knowledge and influence. As a result, conservationists need to look beyond their traditional strongholds and collaborate with other sectors, including social, political, and health: conservation alone can no longer protect biodiversity.

Even among and within conservation organizations, biologists working exclusively within their expertise or particular projects fail to recognize opportunities, capitalize on synergies, or bridge the gaps that could maximize efficacy. This proclivity is not limited to the world of science as we have all been accused of not "thinking outside the box" at some point. When implementing potential solutions, conservation strategies may require broader, multidisciplinary approaches to meet any realistic expectation of success, but conservationists often lack the time, capacity, or resources to engage the appropriate sectors that can better address social-, political-, and/or economic-based challenges.

The narrow focus of projects, sometimes imposed by donors, further reinforces segregation and isolation. Projects that target wildlife ecology may overlook the opportunity to collect biological samples that could assist with management strategies, as the knowledge of baseline population health can help detect trends and identify potential new threats. Ecological studies that require animal capture, such as radio-collaring, offer a unique opportunity to collect biological samples. When pronghorn antelope were radio-collared in the Upper Green River Basin, Wyoming, to identify migration corridors (Fig. 18.2), measurements and biological samples were simultaneously collected to test for pregnancy rates and stress levels as part of a comprehensive effort to establish comprehensive baseline information about pronghorn antelope ecology (Beckmann et al. 2008). Gillespie et al. (2008) discuss multiple invasive and noninvasive sampling techniques to monitor for infectious disease and parameters of health in wild primates for both the conservation of wild animals and the safeguarding of human health. While humans and wild primates are at particular risk of epizootic and zoonotic disease due to our close evolutionary relationship, the same sampling techniques and data can be used across taxa for similar means.

Fig. 18.2 Net-capturing pronghorn in Wyoming (Photo: J. Berger)

The illegal trade in wild flora and fauna or parts is another global issue that threatens biodiversity and health but is confounded by regional, social, political, and cultural divides. Despite international and national regulations, the lack of capacity and global coordination hampers law enforcement in the illicit movement of wild species worldwide. Fuelled by greed and ignorance and sheltered by cultural and social beliefs, this billion-dollar trade offers an unparalleled "free ride" for species and their pathogens to travel the globe, enter new environments, and invade or infect naïve populations. Gomez and Aguirre (2008) identified 29 pathogens diagnosed and documented in illegally traded wildlife included numerous epizootic, zoonotic, emerging and re-emerging infectious diseases. Conservation organizations need to collaborate within and among themselves as well as engage influential sectors beyond conservation to tackle the source of the problem, as well as develop strategies to mitigate the effects. In November 2012, US Secretary of State Hillary Clinton called for a "concerted global response" (WWF 2012b) to address wildlife trafficking, a multinational criminal activity that rivals drugs and human trafficking—and only with the joint efforts between countries and between disciplines can this trade be halted.

With human populations surpassing the seven billion mark in 2011, the rate of anthropogenic change is accelerating and conservationists need to capitalize on all available resources, including fellow scientists, local communities, as well as experts from the development, health, and policy arenas. Preconceived ideals and standard definitions need to evolve in order to keep pace with society, science, and development, and a holistic approach that recognizes the new conservation paradigm—one that includes people and livelihoods—is an important strategy for shared goals and, ultimately, our shared future.

18.3 Redefining Health

The traditional, antiquated, and most common definition of health as the "absence of disease" applies primarily to human health and is limited in scope, depth, and applicability in the twenty-first century. Even the meaning of human health, as it stands, can be contested and needs further rejuvenation to connect with a globalized world. Health is an elusive term that can be defined as a continuum between illness and wellness, partly determined by each individual's ability to cope with and adapt to stress (Lyon 2000). Health is not "black and white," but encompasses a range of indices including physiological, psychological, spiritual, cultural, and developmental. Perhaps, health needs to always be used in conjunction with "well-being," the latter encompassing all non-disease factors, particularly those that pertain to our environment? Nevertheless, we need to realize that health, a constant undercurrent in our daily lives, affects living organisms, the environment, and even global economies. Just as the term "conservation" needs reevaluation, health requires an updated characterization beyond merely remedying a malady.

The epidemiology and transmission of infectious disease are altered by rapidly changing environments, particularly in light of burgeoning human populations that decrease proximity between and among humans and animals, degrade natural habitats, and deplete resources. In developing countries already plagued with overpopulation, flagging economies, corruption, and the lack of capacity, resources, and education, diseases can have resonating impacts on the immediate populations of humans and animals as well as the ecosystem, further underscoring the importance of understanding the linkages between all three. Through complex, integrated mechanisms that we still struggle to comprehend, the health of one can have cascading and/or compounding effects on the others, and the condition of the environment can directly or indirectly affect the health and well-being of humans, with the most obvious consequences at the nexus of livelihoods and the environment. These relationships need to be recognized and health needs to be addressed as a whole. Simultaneously, the human health community needs to appreciate that while human health is the priority, it is closely linked to animal and ecosystem health, and any imbalance in this trifecta can topple the delicate equilibrium, affecting the status of all three.

18.4 Disease: An Ecological Concept

The last century witnessed vast changes in our understanding of disease. Germ theory revolutionized human healthcare, providing scientific grounds to identifiable pathogens as agents of disease. Two medical milestones quickly followed: the development of vaccines and antibiotics as the cornerstones of preventive care and treatment, respectively. Prior to this, medicine could treat clinical signs and provide palliative therapy, such as cough suppressants and fever reducers, but afterwards,

we could identify and treat the proximate cause of disease by preventing and eliminating infection of causative agents. Subsequently, we have increasingly recognized more ultimate causes of disease such as diet, exercise, lifestyle, and heredity. Discoveries in the field of genetics and the development of molecular medicine have transformed how we understand and approach predisposition to and development of disease. We increasingly understand that infectious disease is not as the simple result of infection by a specific pathogen, but as the end product of ecological processes.

Understanding health as an ecological concept requires that we understand disease as a natural process. It is inaccurate and presumptuous to assume that the sole absence or presence of disease equates a healthy or unhealthy individual, community, or environment. Individuals and populations are likely always to naturally harbor pathogens or other organisms. Understanding the health continuum is far more pragmatic than attempting to purge each individual or population of disease. So we must approach health at the ecosystem level rather than at the organismal level and adopt a comprehensive, well-rounded definition of "health."

Examples of the advantages of understanding disease at an ecosystem level and applying this knowledge have already begun to appear. In one case, the use of locally occurring copepods (crustaceans) to control mosquito (*Aedes aegypti*) populations resulted in drastic reductions of the incidence of dengue disease in several communes in northern and central Vietnam (Nam et al. 2005). The implementation of community-based programs to educate and build capacity in local communities allowed the eradication of the vector by populating the mosquitoes' breeding sites with local predacious copepods. In this example, a strong community approach addressing a predominant human health problem through a collaboration of health education and understanding of vector ecology resulted in strong and sustainable outcomes, whereas the application of pesticides would probably result in greater costs and dependence of the communities, unpredictable side effects on the environment, and, most importantly, a less effective control of the disease.

Using such an ecological approach to address disease redirects our focus from treatment to prevention. Rather than intervene after the emergence of a disease, might it not be more pragmatic, beneficial, and cost-effective to detect and prevent the occurrence where possible? Instead of treating patients stricken with malaria, it would be more effective to prevent the initial infection by minimizing vector-host interfaces, a measure that may involve understanding the fields of vector ecology, sociology, health, and education.

The severe acute respiratory syndrome (SARS) epidemic, which caused close to 800 human deaths worldwide between 2002 and 2003 (CDC 2005), is caused by a coronavirus infection that manifests as a respiratory disease in humans. Through globalized air travel, an outbreak rapidly escalated and teetered on pandemic status, infecting over 8,000 people in 37 countries. However, SARS could have been detected and potentially prevented through disease surveillance in wild animals and the enforcement of policies on the illegal movement and consumption of wildlife in Southeast Asia. Three species of cave-dwelling bats were ultimately found to be the reservoir for SARS-like coronaviruses (Li et al. 2005). These animals are often sold

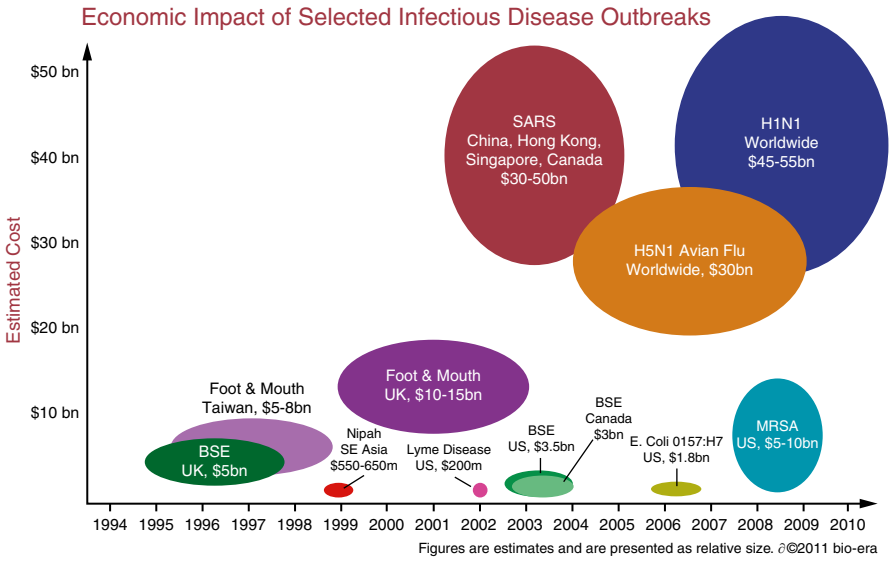

Fig. 18.3 Disease economics (Credit: bio-era)

in wet markets, and although the transmission dynamics are not clearly delineated, this virus likely infected humans through intermediary hosts like civets, which are heavily traded for food (Black 2005). While scientific laboratories and pharmaceutical companies are vying to develop vaccines, perhaps human health and conservation partners should simultaneously collaborate with governments and communities to stop the trade in wild species which would benefit all sectors? This trade not only impacts biodiversity and health but also global economies (Fig. 18.3). Increasing pressure, particularly from governments, national Ministries of Health, and multilateral agencies such as the United Nations, would add weight to flagging policies and possibly bolster national enforcement, as evidenced by US Secretary of State Hillary Clinton's speech to strengthen the enforcement of wildlife laws globally (Staziuso 2012).

18.5 Healthy Animals, Healthy People, Healthy Ecosystems

We like to tackle health and conservation as separate entities: conservationists work with wildlife and human health experts work with people. Meanwhile, threats to the two sectors can be one and the same, or both can face similar challenges where synergy could facilitate or expedite resolutions. However, despite years of attempting to engage multiple disciplines and "cross-pollinate" to address the broader issues, there have been few successes to date, and we continue our compartmentalized approaches to conservation and health. Not only is this unproductive, but as we

progress along our path of rapid development, conservation and health may both suffer if we do not capitalize on linkages and alliances.

Human and animal health are affected by changes in ecosystem health, which include biodiversity loss and climate change. It is difficult to quantify the net impact of biodiversity loss on human health and well-being, but because biodiversity is necessary for functioning ecosystems, its loss results in decreased nutritional security, medicinal resources, and critical ecosystem-derived goods and services. The World Wide Fund for Nature's (WWF's) Living Planet Report (WWF 2012a) indicates that between 1970 and 2008, biodiversity declined by 30 % (60 % in the Tropics), and this trend seems to be continuing. While the direct consequences of water and food shortages are easily recognized, many impacts of ecosystem degradation on humanity can be difficult to assess due to displacement in time and space. The underappreciation of these fundamental relationships, particularly by policymakers and the public, results in conservation and natural resource management being a low priority (Grifo and Rosenthal 1997). However, we must recognize that our health derives from ecosystem health and we need to value healthy ecosystems for our own sake.

Malaria, a vector-borne disease caused by *Plasmodium* parasites, relies closely on its environment. Within the parasite's complex life cycle, transmission requires appropriate habitat for the mosquito vector, such as standing water, and human activities, such as changing land-use patterns, that bring the host in contact with the vector. In many parts of tropical Asia, vast tracts of primary forests are being razed for rubber and oil palm plantations at an astonishing rate. In addition to the loss of the forests, biodiversity, and associated ecosystem services (Ziegler et al. 2009), land-use changes are likely altering disease incidence as well: rubber plantation workers may be at greater risk for contracting malaria due to increased exposure and vector proliferation (the standing water caught in sap collection cups provide habitat for mosquito larvae). The malaria researcher at the end of the microscope attributes increased disease prevalence to the trees, but in fact the true problem originates with deforestation, the conversion of forests to agricultural monocultures, and the system of rubber production. Ecosystem imbalances are largely unpredictable but seem to favor the dominance of generalist species that often become overabundant hosts or vectors (Molyneux et al. 2008). Given that expanding monoculture rubber plantations are a major threat to native forest ecosystems in parts of the world, we must consider that in this case there can be a solution that satisfies human health as well as conservation objectives. This interface is where malaria researchers, industry, health experts, policymakers, and conservationists need to focus.

A plethora of other indirect and deferred health impacts of environmental change also exist, including those resulting from climate change: increasing sea level, ocean temperatures, and acidity as well as severe weather events. Global climate change and its major driver, the burning of fossil fuels, are altering the ecology of disease by their effects on vectors and hosts and the exacerbation of the intensity and frequency of weather extremes. Global warming drives changes in vector and host distribution, and hence, vector-borne diseases are expected to expand to higher latitudes and altitudes. The increase in weather events such as hurricanes and

droughts creates opportunities for the rapid expansion of vector and host numbers and range. When coupled with infrastructural damage and human displacement, these events can have catastrophic and enduring impacts on all sectors.

Predicted shifts in global temperatures and precipitation are anticipated to increase incidence of diseases such as yellow fever, plague, Lyme disease, malaria, and avian influenza (Dell'Amore 2008). Leptospirosis, a waterborne bacterial disease disseminated by rodent urine, is often associated with flooding, and outbreaks followed the severe floods in the wake of Hurricane Mitch in Central America. The abundance of the dengue vector mosquitoes (*Aedes aegypti*) has been shown to increase with warmer temperatures in Thailand, Honduras, and Nicaragua (Molyneux et al. 2008). Cholera, a waterborne bacteria (*Vibrio cholerae*), is generally considered a disease of poor sanitation, but studies have shown that cholera is also influenced by the environment (rainfall, sea surface temperatures), hydrology, and weather patterns (Shah 2011), and these can play a pivotal role in the disease dynamics (Koelle 2009). The effective management of future cholera outbreaks requires collaborations between bacteriologists, human health experts, climate scientists, meteorologists, ecologists, and hydrologists.

The study of climate change is a relatively "new" science, and baseline research to evaluate its impacts on human health and well-being has only just begun. Despite unpredictability and the possibility that distribution changes may not necessarily imply changes in the net range of these diseases (Laferty 2009), the shift in pathogen, vector, or host distributions itself implies exposure of naïve human and animal populations to novel pathogens and the creation of new equilibriums. In addition to changes in disease dynamics, the fluctuations in temperatures, and the associated environmental alterations and interactions, could test the resilience of life on Earth. Climate change challenges the adaptability of human settlements by altering water and food security, affecting shelter availability, generating extreme climatic events, and promoting population migration (Costello et al. 2009). With this in mind, ecosystem services that regulate climate change and protect healthy ecosystems from extreme weather events are integral to "One Health" as well as conservation. Being able to predict climate change effects and subsequent ecological changes will be essential to allow early detection of trends and development of measures to mitigate the effects of these changes on global health.

Often linkages between climate change and health are indiscernible because, besides displacement in time and space, the resulting consequences are biased by global inequities in resource consumption: the people suffering the most severe impacts may not be the primary drivers of environmental degradation or resource exploitation. WWF's Living Planet Report (WWF 2012a) indicates that high-income countries have ecological footprints fivefold greater than that of low-income countries, yet our consumption of natural resources continues to increase: we have now exceeded the Earth's capacity to support our activities. The United States comprises 5 % of the world's population but consumes 25 % of the world's fossil fuel resources (World Watch Institute 2012). It is this disparity that further confounds assessments of linkages between climate change, environmental degradation, biodiversity loss, and human health.

Threats to human health and environmental degradation are often fueled by the same socioeconomic factors and may in turn exacerbate them. Therefore, to focus on only one of these domains will ultimately result in modest and short-lived results. We must recognize these trends and identify their socioeconomic drivers in order to address them in a proactive, pragmatic, and comprehensive manner by intervening at the most effective entry points. Deforestation, rapid agricultural development, water mismanagement, urbanization, and climate change increase the burdens of infectious and noninfectious disease. Measures that threaten biodiversity in order to benefit human health or vice versa are short-sighted, are contradictory, and have the potential to jeopardize both.

In order to maintain healthy people, healthy animals, and healthy ecosystems, there is an imperative need for a collaborative approach that exploits multidisciplinary expertise and resources, while circumventing conflicting measures and policies. This is the key resolution for working towards a sustainable future, where solutions to one problem will not generate yet another, present or future: we cannot discount the interdependence between the health of animals, people, and the environment in global development.

Infectious disease spans the complex animal, human, and environmental interface. While we increasingly recognize the risk of contracting disease from our environment, this epidemiological perspective is limiting and merely identifies unidirectional linkages of disease from human patients to outside sources instead of in a more representative compound model that incorporates fluctuating social, cultural, political, economic, and ecological dynamics. Pathogens do not discriminate, selecting their hosts on the basis of suitability, and human health, while significant to us, is merely one small component of disease dynamics.

Infectious disease is a natural part of all ecosystems; however, anthropogenic pressures on wildlife populations can include and amplify their consequences (Brito et al. 2012). By influencing and possibly altering disease ecology, we not only exacerbate the threat of extinction for some species but also expose the health of humans and animals to the emergence and reemergence of pathogens (Daszak et al. 2000). This interdependence is illustrated by the emergence of the Nipah virus, a lethal zoonotic paramyxovirus that killed over 100 people in an outbreak in Malaysia in the late 1990s (Daszak et al. 2013). The outbreak investigation revealed that the zoonotic pathway of the disease originated from fruit bat droppings that spilled over to humans through the infection of domestic pigs. However, both the reservoir (fruit bats) and the virus were shown to occur historically in the area, and it is likely that they have long coexisted with pig farms. Daszak and colleagues (2013) postulated that two major changes allowed the intensification of this interface upset the balance, allowing the Nipah virus to "spill over" into humans. According to the authors, agricultural intensification—increased pig farming—created a pathway for repeated transmission of the virus from fruits bats to pigs, which could also have been exacerbated by alterations in bat distribution due to forest fires and climatic oscillations. The second condition was the priming effect that the first infections had on the pig populations, allowing the animals to acquire enough immunity to sustain the virus within the population long enough to transmit it to humans, instead of just resulting

in massive pig mortalities. This outbreak clearly demonstrates the consequences of toppling the fragile equilibrium between the health of ecosystems, animals, and humans.

The reality is that the health profession, human or animal, alone is not equipped to consider all ramifications of decisions made on this scale. Continuing with the malaria example, a physician's training is not intended to estimate the devastating effects deforestation can have on the health and well-being of a community, even if models suggest it can reduce malaria-bearing mosquitoes. The analogy to classical medicine would be that the negative side effects of the treatment (in this case, deforestation) could greatly outweigh the elimination of the targeted sickness (in this case, malaria). Destroying forests to eradicate malaria, the most direct action in this microcosm, is irrational once we look beyond the microscope. This course of action would be as irresponsible as the wanton use of antibiotics. In the light of the emergence of drug-resistant pathogens, for example, multi-drug-resistant *Staphylococcus aureus* or extensively drug-resistant tuberculosis, the medical profession now calls for judicious use of medicines in order to be ever mindful of the global consequences of our choices.

Similarly, the unintentional release of the nonsteroidal anti-inflammatory drug diclofenac into the environment in the 1990s decimated vulture populations in Pakistan and India. In this region, vultures fulfill a vital ecological role scavenging animal and human remains and rapidly divesting of decomposing matter before the onset and proliferation of pathogens. In essence, vultures recycle nutrients back into the ecosystem and reduce disease incidence in the environment, but their role extends into cultural, environmental, and socioeconomic benefits (Markandya et al. 2008), all directly or indirectly contributing to human health and well-being. With

Fig. 18.4 White-rumped vulture (*Gyps bengalensis*), a species that is now critically endangered due to the unintended release of pharmaceuticals (diclofenac) in the environment (Photo: A. Michaud)

up to a 99 % decline in white-rumped vulture (*Gyps bengalensis*) populations across the Indian subcontinent (Prakash et al. 2003), the loss of vultures has potentially caused a rise in other scavengers such as rats and dogs, increased pollution from decomposing carcasses, economic losses resulting from dog bites, and the spread of diseases such as rabies (Fig. 18.4). Thus, the unintentional introduction of a pharmaceutical drug into the environment has triggered events that have profound implications on both biodiversity and health.

The construction of the Three Gorges Dam in China's Yangtze River system provides yet another striking example of the ecological underpinnings of health (Kittinger et al. 2009). While the ultimate purpose of the dam was to improve human well-being through energy production, flood control, and economic stimulus, its construction altered an expanse of the Yangtze riparian system, a biodiversity hotspot. This ecological disturbance likely contributed to extinction of the Yangtze River dolphin (*Lipotes vexillifer*) and jeopardizes the habitat of several threatened terrestrial species, including flagship species such as the golden monkey (*Cercopithecus mitis*). The redistribution of water and the creation of the reservoir may also increase the incidence of waterborne diseases such as schistosomiasis and allow for the accumulation of environmental pollutants such as heavy metals, toxins, and human and animal waste. Expanded habitat for the gastropod vector of schistosomiasis and the increased exposure interface resulting from the displacement of up to four million people could cause this debilitating and infectious zoonotic parasite to proliferate. The Three Gorges Dam massively altered an important waterway and disrupted vital ecosystem under the guise of improving human livelihoods and temporary economic gain, but at what cost? Do the negative and irreversible costs to the environmental and health outweigh its short-lived benefits? Misgivings about the net benefits of the project raised by the conservation sector are not merely about the protection of charismatic species, nor do they intend to deny people the benefits of affordable electricity or flood control. Critics of the dam cite a range of issues from human rights to human health. A systematic and holistic evaluation of the project underscores what we have reiterated in this chapter from the outset: that human health and well-being derives from the health of an entire ecosystem and extreme disruptions of ecosystems jeopardize all of our well-being.

The Three Gorges Dam is considered by many to be a catastrophe, not only from the conservation and environmental perspective. Projects that alter ecosystems raise concerns that span conservation and health, as well as many other related or outwardly disparate disciplines, including the political and cultural sectors. If we continue to work within our professional "bubbles," solutions will remain elusive, fragmented, and difficult to implement in a manner that addresses cross-sectoral issues such as conservation and health. From lessons learned, we should be equally conscientious when recommending treatments, interventions, and solutions for ecological disease processes such as vector-borne and waterborne disease. To approach health and disease management at the ecosystem level, we must see beyond just the end goal and consider the value of the ecosystem as a functional unit from which countless services are derived. This ecological approach to community, population, and global health requires cross-trained professionals, multidisciplinary teams, and broad-spectrum, multilateral cooperation.

18.6 Health in a Globalized World

People, animals, and food move at an unprecedented pace in our globalized world. This happens at a scale that confounds traditional knowledge of disease epidemiology and transmission and thwarts detection, prevention, and mitigation. Pathogens can "hitch" rides on hosts and via airplanes, trains, buses, and boats and can be on the other side of the globe among a naïve population of humans and animals within days, maybe even hours—"biological warp speed," as coined by virus hunter Nathan Wolfe (Wolfe 2009). The increasing density and connectivity of human settlements create the perfect environment for rapid escalation of an outbreak into epidemics and pandemics.

The scale and rate of the global food trade encumbers detection and control of food-borne illnesses, and the once local impacts of salmonella outbreaks, for example, can nowadays assume a totally different scale due to rapid mass distribution. This is evidenced in the periodic Eshcerichia coli (E coli) outbreaks in recent years that were able to spread far and wide prior to their detection and identification (WHO 2011). Globalization also has the power to accelerate and amplify the natural processes of genetic recombination and viral mutations as seen in new, more virulent strains of E. coli (Muniesa et al. 2012) as well as highly pathogenic avian influenza (HPAI) virus.

Moreover, it is important to understand the far-reaching social and economic consequences of diseases in a globalized world. Even diseases that are not fatal to humans or animals can have profound social and economic effects, hampering development and ultimately affecting human health and livelihoods. Foot-and-mouth disease (FMD), an infectious viral disease in wild and domestic cloven-hoofed animals, is endemic in seven out of ten Southeast Asian countries. While mortality is relatively low with this disease, morbidity impacts livestock production and national economics by limiting the growth of the livestock trade through international export. FMD-free countries will not import meat from endemic countries, and the economic losses cascade through the production chain, affecting human livelihoods. The inability of developing countries to advance their livestock production sector limits national economic growth and potential livelihood income, underscoring the direct and indirect linkages between animal and human health and well-being.

Sobering cases of globalization and the spread of disease emerged, and reemerged, with periodic Ebola outbreaks, severe acute respiratory syndrome (SARS), and highly pathogenic avian influenza (HPAI). The very real and rapid spread of these viruses captured the global spotlight and their sensationalization brought the reality of our growing dilemma to the public domain: while information (accurate or otherwise) is transmitted around the globe instantaneously, our preparedness to contend with epidemics and pandemics lags behind. In 2002 and 2003, a coronavirus, SARS, confirmed this reality by spreading from Hong Kong to 37 countries in a matter of weeks and nearly achieving pandemic status. It took the threat of pandemic avian influenza in the mid-2000s to prompt large-scale, multilat-

eral, multidisciplinary projects to predict and prevent emerging pandemic threats—efforts that continue today.

This new globalized reality has led to the need for an updated approach to "One Health" that can complete the medical view with perspectives on social, environmental, and demographic dynamics on a global scale. Addressing health and disease holistically, and looking beyond geographic, political, social and scientific boundaries, will be the only course to keep pace with globalization.

18.7 Bridging the Gap

As with all complex, global issues that transcend geographical, social, cultural, and political boundaries, there is no panacea. However, the innovative "One Health" approach and its arsenal of tools can help bridge the divide between conservation and health and facilitate effective, collaborative strategies. The recurring theme in this chapter emphasizes the need to recognize critical linkages and capitalize on multidisciplinary expertise to strategically address cross-sectoral challenges make pragmatic decisions that consider the long-term ramifications of cross-sectoral tactics.

We can no longer work, isolated, in our respective realms of expertise: we need to address conservation and health as a unified entity, engage appropriate groups, identify synergistic opportunities, develop multidisciplinary strategies, and implement projects that bridge areas of expertise that may appear to be dissimilar. Acknowledging the limitations of our own capabilities is the first hurdle. Few conservationists excel at developing social projects, and likewise, not many wildlife veterinarians have the skills to effectively engage policy makers. While each individual and each field is constrained, there are potentially endless expert partners and innovative synergies.

So it does not end with the malaria expert, the microscope, and the Petri dish. Back at the meeting, the sole conservationist in the room raised her hand and asked: "The trees seem to be responsible for development's short-sightedness: what if we could work with human disease experts and the rubber plantation owners to develop strategies as simple as covering the sap collection cups to reduce mosquito breeding and educate plantation workers on disease prevention?"

References

Beckmann JP, Berger KM, Young JK, Berger J (2008) Wildlife and energy development: pronghorn of the Upper Green River Basin – year 3 summary. Wildlife Conservation society, Bronx. Available at: http://www.wcs.org/Yellowstone

Black R (2005) Bats a 'likely source' of Sars. BBC. Available at: http://news.bbc.co.uk/2/hi/science/nature/4291386.stm

Brito D, Moreira DO, Boutinho BR, Oprea M (2012) Ill nature: disease hotspots as threats to biodiversity. J Nat Conserv 20:72–75

CDC (2005) SARS basic fact sheet. Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/sars/about/fs-SARS.html

Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R et al (2009) Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet 373:1693–1733

Daszak P, Cunningham AA, Hyatt AD (2000) Emerging infectious diseases of wildlife – threats to biodiversity and human health. Science 287:443–449

Daszak P, Zambrana-Torrelio C, Bogich TL, Fernandez M, Epstein JH, Murray KA, Hamilton H (2013) Interdisciplinary approaches to understanding disease emergence: the past, present, and future drivers of Nipah virus emergence. Proc Natl Acad Sci 110(Supplement 1):3681–3688

Dell'Amore (2008) http://news.nationalgeographic.com/news/2008/10/081007-climate-diseases.html

Erlich PR, Wilson EO (1991) Biodiversity studies: science and policy. Science 253:758–762

Gómez A, Aguirre AA (2008) Infectious diseases and the illegal wildlife trade. Ann N Y Acad Sci 1149(1):16–19

Gillespie TR, Nunn CL, Leendertz FH (2008) Integrative approaches to the study of primate infectious disease: implications for biodiversity conservation and global health. Yearbook Phys Anthropol 51:53–69

Grifo F, Rosenthal J (eds) (1997) Biodiversity and human health. Island Press, Washington, DC

Kittinger JN, Coontz KM, Yuan Z, Han D, Zhao X, Wilcox BA (2009) Toward holistic evaluation and assessment: linking ecosystems and human well-being for the Three Gorges Dam. EcoHealth 6:601–613

Koelle K (2009) The impact of climate on the disease dynamics of cholera. Clin Microbiol Infect Suppl 1:29–31

Laferty KD (2009) The ecology of climate change and infectious diseases. Ecology 90:888–900

Langlois EV, Campbell K, Prieur-Richard A-H, Karesh WB, Daszak P (2012) Towards a better integration of global health and biodiversity in the new sustainable development goals beyond Rio_+ 20. Ecohealth 9(4):381–385

Li W, Shi Z, Yu M, Ren W, Smith C, Epstein JH, Wang H, Crameri G, Hu Z, Zhang H, Zhang J, McEachern J, Field H, Daszak P, Eaton BT, Zhang S, Wang LF (2005) Bats are natural reservoirs of SARS-like coronaviruses. Science 310(5748):676–679

Lyon B (2000) Stress, coping and health: a conceptual overview. In: Rice V (ed) Handbook of stress, coping and health: implications for nursing research, theory, and practice. Sage, Thousand Oaks, pp 3–23

Markandya A, Taylor T, Longo A, Murty MN, Murty S, Dhavala K (2008) Counting the cost of vulture decline—an appraisal of the human health and other benefits of vultures in India. Ecol Econ 67:194–204

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: health synthesis. United Nations Environment Programme/World Health Organization. Available at: http://www.unep.org/maweb/documents/document.357.aspx.pdf

Molyneux DH, Ostfeld RS, Bernstein A, Chivian E (2008) Ecosystem disturbance, biodiversity loss and human infectious disease. In: Chivian E, Bernstein A (eds) Sustaining life. How human health depends on biodiversity. Oxford University Press, New York, pp 287–324

Muniesa M, Hammerl JA, Hertwig S, Appel B, Brüssow H (2012) Shiga toxin-producing *Escherichia coli* O104:H4: a new challenge for microbiology. Appl Environ Microbiol 78(12):4065–4073. doi:10.1128/AEM.00217-12

Nam VS, Yen NT, Phong TV, Ninh TU, Mai LQ, Lo LV, Nghia LT, Bektas A, Briscombe A, Aaskov JG, Ryan PA, Kay BH (2005) Elimination of dengue by community programs using *Mesocyclops* (Copepoda) against *Aedes aegypti* in Central Vietnam. Am J Trop Med Hyg 72:67–73

Prakash V, Pain DJ, Cunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Sivakumar S, Rahmani AR (2003) Catastrophic collapse of Indian white-backed *Gyps bengalensis* and long-billed *Gyps indicus* vulture populations. Biol Conserv 109:381–390

Shah S (2011) Climate's strong fingerprint in global cholera outbreaks. Yale Environment 360. Available at: http://e360.yale.edu/feature/climates_strong_fingerprint__in_global_cholera_outbreaks/2371/

Staziuso J (2012) Efforts to combat illegal wildlife trade will be stepped up. Says Hillary Clinton. 9 Nov 2012, Huffington Post. Available at: http://www.huffingtonpost.com/2012/11/09/illegal-wildlife-trade-trafficking-us-clinton_n_2100844.html

WHO (2011) Bulletin of the World Health Organization 2011;89:554–555. doi:10.2471/BLT.11.040811

World Watch Institute (2012) The state of consumption today. World Watch Institute. Available at: http://www.worldwatch.org/node/810#3

Wolfe N (2009) Nathan Wolfe: the jungle search for viruses. TED Talks. [video file] Available at: https://www.ted.com/talks/nathan_wolfe_hunts_for_the_next_aids

WWF (2012a) Living planet report 2012. World Wide Fund for Nature. Available at: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/

WWF (2012b) WWF applauds Hillary Clinton's call to stop wildlife crime. 8 Nov 2012. Available at: http://wwf.panda.org/?206664/WWF-applauds-Hillary-Clintons-call-to-stop-wildlife-crime

Ziegler AD, Fox JM, Xu J (2009) The rubber juggernaut. Science 224:1024–1025. Available at: https://c3.nasa.gov/nex/static/media/publication/Science5-22-09.pdf