

NATURE AND HEALTH

EMERGING KNOWLEDGE INFORMS NEW POLICY DIRECTIONS

NOOSHIN RAZANI, MD, MPH, GUEST EDITOR

Beyond COVID-19: Conserving nature to prevent the next pandemic



Tierra Smiley Evans, Zoë Grange, Jaber Belkhiria, Jennifer Lane, Brooke Genovese, Eri Togami & Jonna Mazet • *One Health Institute, University of California, Davis*

Corresponding author

Tierra Smiley Evans
One Health Institute
School of Veterinary Medicine
University of California, Davis
1089 Veterinary Medicine Dr.
Davis, CA 95616
tsmevans@ucdavis.edu

All authors contributed equally.

Introduction

The COVID-19 pandemic has unimaginably changed our lives with long-lasting consequences for our society, environment and the global economy. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for the COVID-19 pandemic, is just one of the many pathogens that have already emerged in humans as a result of interactions with wildlife and is only one of the many to come if we do not reduce our impacts on natural systems. While the immediate priority is to tackle the COVID-19 public health emergency, our parallel and long-lasting response must focus on addressing the root causes of pandemics. Human and animal health are inextricably linked with the pathogens they carry and the ecosystems that are shared. The degradation of nature disturbs this delicate balance between microbes, their natural hosts, and environments—driving the emergence of disease (IPBES 2019).

Our society has the opportunity to change the way we perceive and interact with nature, including the animals and environments we share. Everyone can

contribute toward preventing the next pandemic, be it by reducing our own environmental impact, creating outdoor sanctuaries for wildlife habitat, protecting the national parks and key biodiversity areas, or developing the next vaccine—we all have a role to play.

“One Health” is a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment. The concept has been around for some time, bringing together professionals and policymakers across sectors, including public health, medicine, livestock, forestry, natural resources, agriculture, and environment, to address our world’s most pressing health challenges, such as COVID-19. While the One Health approach has made great strides in the past decade, more silos remain to be broken down, and now is the time to clearly establish the connection between our planet’s health and human health in our collective mindsets. We aim to illustrate how human behaviors have resulted in

global systems-level changes that enable pathogen emergence, the important lessons to be learned, and how we can safeguard our relationship with nature to prevent future pandemics.

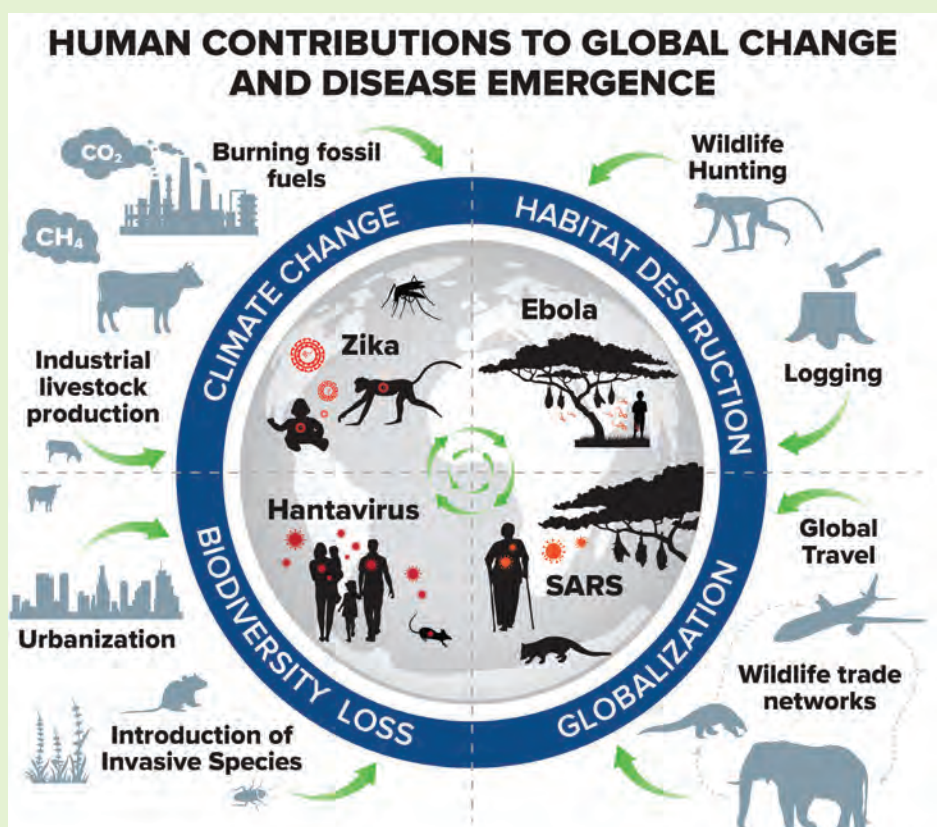
Our role in the Anthropocene pandemic era

People have influenced and been shaped by the forces of zoonotic disease for thousands of years. The Black Death, or the Plague, caused by the bacterium *Yersinia pestis*, resulted in the death of up to a quarter of the world's population during the mid-1300s and changed the course of human history. The outbreak was initially associated with climate and rodent density fluctuations in Asia, but its spread in Europe was linked to human overpopulation. Since then, our population has exponentially grown and become ever-more connected. We now live in the “Anthropocene pandemic era” (Lewis and Maslin 2015), in which human-driven global changes are intimately tied to the increased risk of disease emergence and likelihood of a pandemic.

Human activity impacts our forests' ability to provide essential ecosystem services such as carbon sequestration and sustaining biodiversity. Between 1990 and 2020, there was a net loss of 178 million hectares of forest, an area approximately the size of Libya (FAO and UNEP 2020). With this disturbance, there has been a corresponding increase in zoonotic disease emergence in regions undergoing rapid forest change (Allen et al. 2017). As forests are cleared, humans expand into new areas and contact new wildlife populations, providing unprecedented opportunities for pathogen spillover. The forest region in rural Guinea, where the West African Ebola virus epidemic emerged, had been subject to extreme deforestation, caused by mining and lumber operations. These activities impacted the availability of bat habitat, forcing people and bats into more intimate and frequent contact—facilitating the epidemic (Figure 1).

Agricultural and aquacultural expansion are

Figure 1. Human contributions to global change and examples of disease emergence. Through human activities that have contributed to habitat destruction, globalization, climate change, and biodiversity loss, humans have driven the emergence of disease.



> *One Health is a collaborative, multisectoral, transdisciplinary approach working at local, regional, national, and global levels*

the main drivers of deforestation globally (FAO and UNEP 2020). The design of many modern industrial farms is particularly vulnerable to outbreaks of disease, given the high density of animals and mixing of different species that promote pathogen spread and cross-species transmission. The 2009 H1N1 pandemic originated from a reassortment of avian and swine influenza A viruses, likely in agricultural settings, and resulted in as many as 575,000 global human deaths ([cdc.gov](https://www.cdc.gov)).

While domestic agriculture provides the dominant source of protein around the world, many societies still depend on wildlife for food, income, and as part of their cultural practices. Some communities have sustainably hunted wildlife for centuries, presumably avoiding large-scale animal-sourced or “zoonotic” outbreaks. However, increasing demand for wild animal products, driven by pressure from outside of subsistence communities, including the wild animal trade, can lead to unsustainable hunting practices and biodiversity loss, which contribute to the spread of disease. Most theories on the origin of SARS-CoV-2 suggest bat species were the source, possibly mixing with an intermediate animal host that then facilitated spillover to humans. We now know that a similar scenario involving a live animal market likely led to the emergence of SARS-CoV, the virus causing Severe Acute Respiratory Syndrome (SARS). Live animal markets provide ideal scenarios for mixing of pathogens among wildlife and domestic species that would otherwise never meet in nature, thus facilitating the opportunity for exponential spread through human-to-human transmission in dense populations (Figure 1).

As a result of our world’s globalization over the past century, including the increasingly interconnected nature of our travel, trade, and resource use, we have significantly impacted our planet’s climate through the release of greenhouse gases—a direct result of burning fossil fuels, deforestation, and industrialized agriculture. The

planet’s average surface temperature has continued to rise since the late 19th century by approximately 1.62^{oF} (0.9°C), and notably most of this warming occurred in the past 35 years (climate.nasa.gov). This global change is significant for disease emergence because changes in climate influence the distribution, abundance, and behavior of vectors, such as mosquitoes and ticks, and animal reservoirs of pathogens. Such events have led to the spread of mosquito-borne arboviruses such as dengue, chikungunya, and Zika to people in more northern latitudes, and large-scale outbreaks of disease.

As a culminating result of the many global changes humans have driven during the past century, some of which we describe above, we have lost 68% of our planet’s vertebrates, equating to the sixth mass extinction in Earth’s history (WWF 2020). In order to prevent the next pandemic, it is critical to understand the relationship between biodiversity loss and human health, and the role preserving nature could play in protecting us from disease.

Biodiversity conservation for public health

The relationship between biodiversity and zoonotic disease risk is complex. Under different circumstances, high biodiversity can be linked to both increases and decreases in disease transmission. High biodiversity can reduce the likelihood of transmission, prevalence, and spillover risk to humans for some pathogens, including *Borrelia burgdorferi* (the bacterium that causes Lyme disease), hantavirus, malaria, and West Nile virus (Keesing et al. 2010). In these pathogen systems, the presence of more animal species that do not transmit the pathogen makes it less likely that the pathogen will contact an animal species that can transmit it, decreasing the overall burden of disease. This process, known as the “dilution effect,” illustrates that biodiversity can protect human health. An alternative theory, the “amplification effect,” suggests that more species result in more abundant sources of potential zoonotic pathogens, or “zoonotic pools,”

presenting an increased risk to human health (Murray et al. 2013). The most accurate scenario likely lies somewhere in between.

Left undisturbed, ecosystem function and its multitude of different pathogen systems regulates life on Earth. However, human activities that disturb nature's delicate balance and alter species diversity and abundance result in unexpected consequences on microbial transmission patterns and infectious disease dynamics. While the unexpected consequences are waiting to be studied, are we willing to defer action to address biodiversity declines and its potentially negative health consequences?

It is estimated that there are over 1.6 million unknown virus species in mammalian and avian populations, of which approximately 500,000 have the potential to infect humans (Carroll et al. 2018). We know little about the ecology of these unknown viruses, but we do know that the relationships among humans, animals, and microbes are inextricably linked. Without detailed knowledge on all of the planet's microbes, we must act under the assumption that the benefits of protecting biodiversity will have net positive effects on human health and may help protect people from future emerging diseases, especially if, by preserving nature, we reduce high-risk interactions with wildlife that are likely to harbor zoonotic diseases. Conservation activities, focused on curbing biodiversity loss, such as protection of wild spaces, have the potential to protect human health by both preserving the protective mechanisms that diverse vertebrate populations may have, and providing safe havens for wildlife to flourish separate from humans.

Preservation of biodiversity takes coordinated and concerted efforts by governments and their stakeholders, buy-in from local communities, and contribution of resources. Nature preservation is no small task under any circumstance but is particularly challenging during times of economic hardship and public health emergencies. However, similar to a pandemic, positive change starts small

and then grows. There are actions that can be taken by every individual, right now.

How we can protect biodiversity for pandemic management and our collective well-being

Connecting individuals with nature—what we all can do. The COVID-19 pandemic has sent much of the world into lockdown, restricting our movements and interactions to curb the transmission of SARS-CoV-2—resulting in many unintended negative consequences. Humans are social creatures: we like to interact with others, including animals. There is a reason why pet ownership is so high throughout the world: we gain mental and physical health benefits from animals. Psychological well-being has also been associated with access to green space, blue space (i.e., aquatic and marine environments), and street trees and private gardens in both urban and rural settings (Hartig et al. 2014; Bratman et al. 2019). Therefore, the health benefits of access to nature should not be underestimated when considering the COVID-19 crisis or managing the next one. Government policies in many countries have allowed physically distanced outdoor exercise during the pandemic, with the physical and psychological benefits of nature thought to outweigh the risks of disease exposure (Razani et al. 2020). During this time, many people have started new outdoor exercise regimes, dusted off that bike that has been sitting in the garage, and started to see nature again for the first time in many years.

Furthermore, there is an increasing body of knowledge surrounding contact with nature and outdoor exercise helping human resilience to infectious diseases through a myriad of potential mechanisms such as the immunoregulatory effects of vitamin D and cascading pathways related to stress and immune function (Kuo 2015; Charoenngam 2020). SARS-CoV-2 is believed to be less effective at transmitting outdoors due to a number of factors, with space and fresh air likely having a dilution effect. The ability to socially distance in metropolitan areas, such as New York City, which has seen one of the highest death tolls

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in the United States, is significantly harder than in rural areas. Now policy-makers are rethinking road and bicycling infrastructure, increasing access to open and shared spaces in urban environments to encourage a continued drive towards a greener and healthier lifestyle.

There are many actions that individuals can take to help protect biodiversity and, in turn, receive the health benefits of connecting with nature. People can help preserve the ecosystems around them. Local habitat restoration, even in your backyard, including planting of native flora and the provision of animal refuges or nesting material, are simple but effective actions that, if taken by many, will aid the conservation of local ecosystems and beyond. Going further, regenerative agricultural practices by small farms that promote soil health restoration, integration of different crop types, and planting of refugia alongside commodity crops can also contribute to biodiversity conservation by providing more natural habitats for animals to thrive.

During times when human connectivity is being forced to be reimaged, we can also look to advances in technology and social media to allow each and every person to play a part in preserving and increasing biodiversity—connecting individuals through a common cause. Wildlife and health monitoring using scientific tools, such as ProMed (promedmail.org) and HealthMap (healthmap.org), have already been developed to draw information from individuals to create alerts that help public health officials. Similarly, applications such as iNaturalist allow citizen scientists to learn about a region's biodiversity and contribute to a global database on species abundance and diversity. Collectively, we can act as a watchdog for unusual public health events and wildlife and plant die-offs in our backyard or local park that, if reported, monitored, and managed effectively, could help halt a future pandemic.

Ecotourism has also been an effective way to connect people with nature. Prior to the COVID-19 pandemic, ecotourism had expanded greatly, often centered around charismatic or “umbrella” species, such as Africa’s “big five” (lion, leopard, rhinoceros, elephant, and Cape buffalo), great apes, and popular marine species like orcas. By focusing attention on charismatic megafauna, you can indirectly protect habitats of other wildlife species and help to maintain entire ecosystems. One example is the mountain gorilla conservation program. Through ecotourism focused on the mountain gorilla, the program has helped protect and even increase the numbers of this endangered species, while preserving a rare ecosystem of cloud forests along with its diverse fauna and flora.

Promoting activities that help to connect or reconnect all kinds of people with nature, be they urban dwellers, amateur science enthusiasts, or travelers, can chart a path for changing our relationship with and protecting nature (Figure 2). Just a small change in mindset could have cascading impacts on biodiversity conservation and pandemic prevention.

Engaging communities to protect their own ecosystems. Disease outbreaks start and end in communities—and so does biodiversity conservation. Regions of the world where economic and health resources are limited often have the greatest environmental pressures. Biodiversity conservation in vulnerable, pristine landscapes requires effective engagement of local communities, especially in the tropics where pandemic emergence risk is high and human development needs are great (Allen et al. 2017). Conservation education about the benefits of protecting wildlife is an important first step. Informing communities of the ecosystem services provided by wildlife, as well as the health risks that can be averted, enables people to make informed choices about the ways in which they interact



Figure 2. Children from an Earth Guardian school count waterfowl at a wetland in Argentina. | F. CANUTI

with and utilize wildlife resources—putting the decisions in the hands of the community members.

Bats provide an important example, as they contribute essential ecosystem services that benefit agriculture and human health, including seed dispersal, plant pollination, and arthropod suppression; however, they are often misunderstood and targets of retaliatory, fear-driven actions. The perceived disease risk associated with some species of bats is often amplified by a combination of poor scientific messaging about their relationship with high-profile pathogens and misrepresentation in the media (MacFarlane and Rocha 2020). Following the discovery of a new ebolavirus in bats in Sierra Leone, researchers collaborated with local partners and communities to provide behavior change strategies for cohabitating with bats. The use of a moderated picture book, *Living Safely with Bats*, which reinforces the multitude of ways humans benefit from bats, gives guidance on avoiding unsafe contact and outlines how to safely manage bats in and around human dwellings. This program

was successful, in part because it targeted activities in primary schools, allowing information to trickle up from children to their parents and families (Figure 3).

Not all community engagement initiatives are entirely successful, and there are lessons to learn from our past challenges. There is a fine balance between conservation and human development and meeting the needs of both determines sustainability. One strategy has been integrating wildlife species conservation efforts into community-based natural resources management (CBNRM) schemes. These programs seek to decentralize management of critical resources, such as wildlife, protected lands, and water rights, by transferring responsibilities for managing and benefits gained from natural resources to local communities. While in principle CBNRM appears to be a win-win opportunity, the impact and success of such programs has had mixed results for wildlife conservation and local communities alike (Milupi et al. 2017).



Figure 3. Community engagement in Sindia Primary school, Guinea, where children are learning about how to live safely with bats, as part of the USAID [US Agency for International Development] PREDICT project. “I realized that it was not good to play with or even touch bats. Since then, I have tried to explain to my parents that bats are important for the environment, but they could carry dangerous diseases”—15-year-old from the forest region in Guinea. | JABER BELKHIRIA

Thoughtful and early community engagement is required to understand local culture, challenges, demands on resources, and needs of citizens. Utilizing “co-creation” frameworks, in which Indigenous communities have a seat at the original planning table, is essential for sustainable biodiversity conservation and its benefits for human health. An example of the importance of early community engagement is the Batwa of Uganda, who were removed from the forest of Bwindi Impenetrable National Park under the auspices of saving the mountain gorillas and their habitat. Despite the Batwa being successful stewards of the forest for many generations, and human development programs to support them after their displacement being implemented simultaneously, they now exist as conservation refugees—a marginalized group, living well below the poverty line on the forest edges (Figure 4). In many lower-income countries, livelihoods are deeply dependent on forest resources. Restricting forest access without

providing livelihood alternatives often results in conflict and increased poverty. To help balance the Batwa’s situational poverty with the goal of preserving Bwindi’s biodiversity, a community hospital (www.bwindihospital.com) was formed to provide free healthcare for the Batwa. Using a One Health approach, the hospital operates under the guiding principle that healthy people are less likely to access the forest for medicinal herbs or to poach wild animals for food or illegally harvest trees for income to pay for healthcare. While this is a small-scale example, local-level One Health initiatives show us the value of connecting health with biodiversity conservation and the potential for impact if this model were expanded.

Success of conservation and public health policies are dependent on effective community engagement. Major global policy agendas for curbing the rate of biodiversity loss have focused on the value of carbon sequestration and other environmental services that protecting forests



Figure 4. Bwindi Impenetrable Forest edge and surrounding Batwa settlements, southwestern Uganda. | TIERRA SMILEY EVANS

provide. Programs such as REDD+ and UN-REDD (the United Nations’ efforts to reduce carbon emissions through deforestation and forest degradation), the Forest Carbon Partnership Facility, and the Forest Investment Program of the World Bank support reimbursements to low- and middle-income countries for effective carbon sequestration. While understood by governing bodies, these programs are rarely tangible at the local level and become a lower priority during times of immediate economic hardship and public health emergencies, such as the COVID-19 pandemic. Integrating public health concepts into conservation policy is a tool that could be especially helpful during these times. The connection between healthy forests and wildlife and human disease is already a concept that is part of numerous Indigenous cultures. In many societies dependent on forests, folklore exists that describes disease emerging from the forest when trees or wildlife populations are harmed. Incorporating these local beliefs into conservation messaging would go a long way toward engaging

communities to participate in preserving their own forests and wildlife.

Strengthening One Health science. Broader science initiatives are needed to investigate the connection between global environmental changes, such as biodiversity loss, and human and animal disease burdens. These initiatives should encourage environmental scientists, public health scientists, veterinarians, physicians, and disease ecologists to work together to answer the fundamental questions about how biodiversity loss impacts human and animal health. Why do levels of disease change as forests are cleared and species are lost? Where do diseases first spill over from an evolutionary host to people? What are the behavior changes that can stop it?

Progress also requires improved evaluation and impact analyses comparing biodiversity conservation efforts across regions and creating an atmosphere in which failures can be freely shared. As in medicine, reports of what doesn’t work are

> Tapping into the vast knowledge of the world's protected area systems and the veterinarians, biologists, and environmental scientists they employ could provide a route for communication between One Health practitioners and policymakers

just as valuable as those of successes. There are well-documented models in other fields, such as that developed by the Institute of Health Metrics and Evaluation, in which global health economists calculate DALYs (disability-adjusted life years) and contrast them against the cost effectiveness of global health interventions. Future science initiatives are needed to establish metrics for calculating a “biodiversity change quotient” that can incorporate health benefits and detriments and be evaluated in light of cost effectiveness of conservation programs.

More specific avenues for scientists to effectively communicate One Health research and findings with policymakers are also needed. Platforms, such as the American Association for the Advancement of Science (AAAS) and the National Academies Science Policy Fellowship programs, among others, are providing scientists the opportunity to communicate with decision makers to ensure new conservation policies and initiatives are “pandemic sensitive.” Tapping into the vast knowledge of the world's protected area systems and the veterinarians, biologists, and environmental scientists they employ could similarly provide a route for communication between “boots on the ground” One Health practitioners and policymakers. Models have also been created by non-governmental organizations, such as the Rainforest Alliance, whose certification program that designates products and programs as following guidelines of sustainability (rainforest-alliance.org) could be adapted to incorporate One Health concepts.

For One Health to truly take a global approach to pandemic preparedness, it also requires a global governing body. Public health has the World Health Organization (WHO), domestic animal health has the Organization for Animal Health (OIE) and the Food and Agriculture Organization of the

United Nations (FAO), and ecosystems have the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), but there is no unifying body for wildlife health. Now is the time for a global wildlife health authority (IUCN 2020). Through such a governing body, international wildlife health standards could be developed, implemented, and overseen. A global wildlife health authority could also provide a mechanism for strengthening the capacity for promoting wildlife health, targeted to regions of greatest need, in areas of highest risk for disease emergence.

A timely example is the debate about whether or not to close the wildlife trade, following the emergence of COVID-19. While ending the practice of wildlife trade could reduce the spread of zoonotic pathogens, an outright ban could also have several unintended effects, including promoting black market trade, increasing demand, and heightening sanitation risks that come with unregulated trade, as well as the effects on the livelihoods of people dependent on these activities. In the past, wildlife trade bans, such as that imposed after the emergence of SARS, were ineffective, and their implementation eroded over time. With a global wildlife health authority, alternative strategies, such as regulating higher- vs. lower-risk species and improving health and hygiene regulations in markets, could be explored and employed. This initiative would fill a major gap in pandemic preparedness—contributing to species survival in some of the world's most biodiverse regions and establishing a unified standard for wildlife disease surveillance and reporting.

Conclusion:

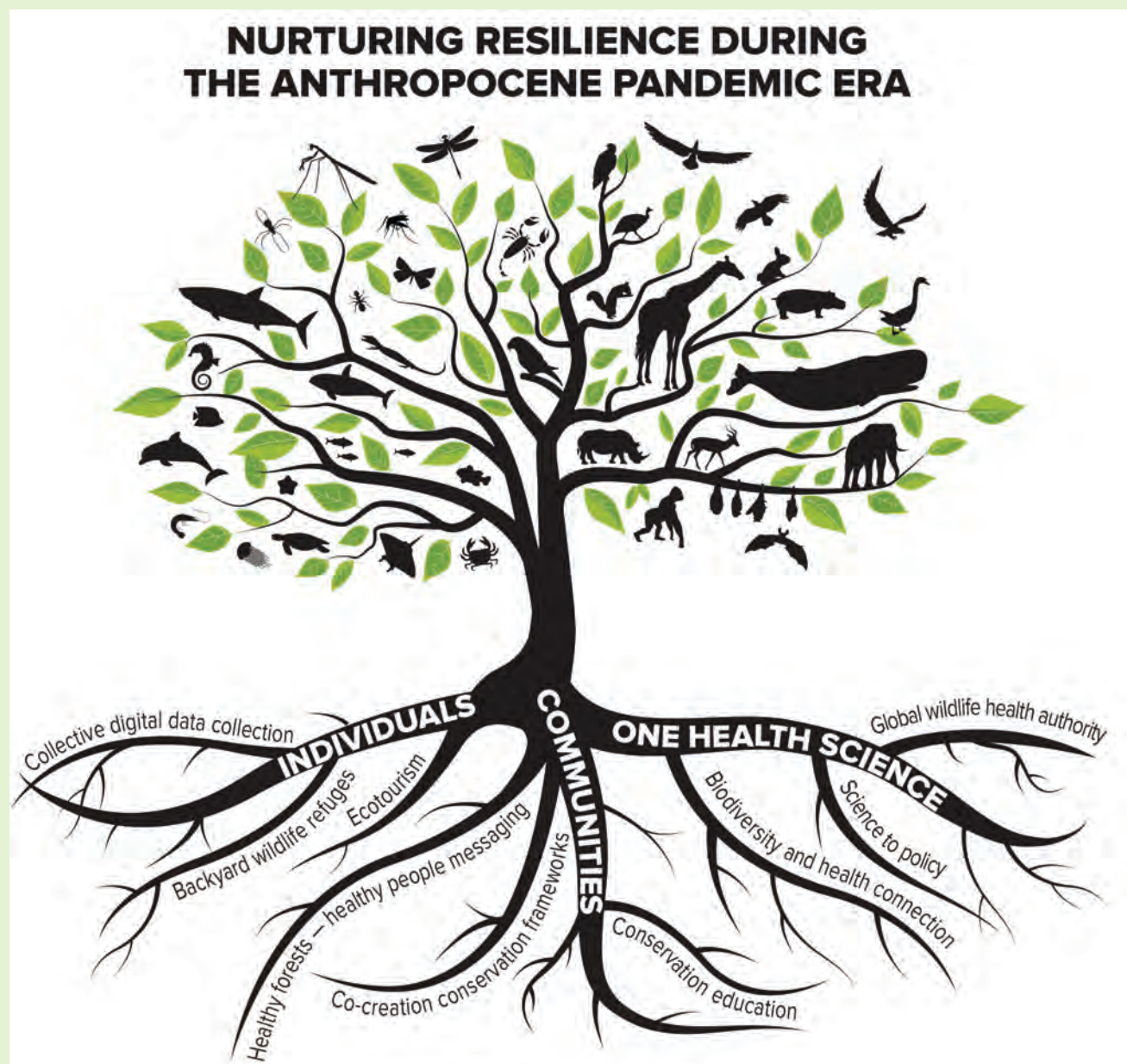
Conserving nature to prevent the next pandemic

The One Health approach has made considerable strides in better connecting public health and animal health policy and operationalizing this

approach in governments around the world. Unfortunately, incorporation of environmental policy in One Health efforts lags behind more clear and pressing threats to health, as often does capacity for promoting wildlife health. In the COVID-19 era, as the world's focus shifts towards recognizing the importance of green spaces that we share with wildlife, we now have the opportunity to strengthen policies and communication surrounding conservation and public health.

The warning signals from our planet are clear. With increasing impacts of climate change, large-scale losses of fauna and flora, and disease emergence events arising from interactions with wildlife hosts, we are experiencing the profound effects of the “Anthropocene Pandemic Era” on human health (Figure 5). Now is the time to mobilize and build on developing One Health platforms to make conservation of nature and open spaces part of the public health agenda. For pandemic

Figure 5. Nurturing Resilience During the Anthropocene Pandemic Era. Through focusing efforts on individuals, communities, and One Health science platforms, we can curb biodiversity loss and change the trajectory of the Anthropocene Pandemic Era.



prevention to be effective, it will take engagement at every level—from communities inspired to protect their local wildlife and environments through programs that consider them as equal stakeholders, all the way to concerted efforts by governments and international organizations. As COVID-19 has shown us, we must recognize our interconnectedness with wildlife and our environment. It is imperative that we preserve nature to protect ourselves; there is no alternative.

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