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# PREDICT

*Advancing Global Health Security at  
the Frontiers of Disease Emergence*



**CITATION**

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**(Cover page)** PHOTO: SIMON TOWNSLEY

# PREDICT

*Advancing Global Health Security at  
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## EXECUTIVE SUMMARY

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# THE PANDEMIC ERA

From the first documented pandemic in 514 AD to COVID-19, infectious diseases, especially those with animal origins, have resulted in an enormous burden on humanity and have threatened our well-being, economic development, and global security. There are an estimated one billion cases of zoonotic diseases in people annually, and numerous other species are threatened or on the brink of collapse from a combination of anthropogenic pressures, including human-driven infectious disease transmission. Epidemics due to emerging viral diseases, in particular those caused by viruses with origins in wildlife hosts, are increasing in both frequency and severity. Spillover of these viruses from wildlife can be directly attributed to human activities. Human-induced landscape change, especially deforestation, intensification of agricultural production, and urbanization associated with human population growth, has disturbed ecological balances, altered transmission dynamics in all hosts, increased contact between people and animals, and driven viral spillover and amplification and spread of pathogens.

These trends coupled with our understanding that human, animal, plant, and environmental health are inextricably linked, have been a driving force for the use of a One Health approach for tackling the multifaceted challenges that emergence of infectious diseases represent. Together with USAID, the PREDICT Consortium pioneered a One Health approach to emerging virus and infectious disease identification, surveillance, and risk communication with collaborative investigations into risks associated with wild animal reservoirs, domesticated species in close contact with wildlife, and people at the highest risk of exposure to zoonotic viruses. Our objective was to use science and discovery to advance insight on features common to emerging pandemic threats globally and enhance risk reduction and preparedness locally, to improve capabilities for stopping pandemic

emergence and spread at the earliest opportunity. From 2009-2020, the PREDICT project made unprecedented progress, strengthening capacity to detect viruses in high-risk settings for zoonotic spillover in many of the world's most vulnerable locations for infectious disease emergence and spread.

## **ONE HEALTH SURVEILLANCE FOR EMERGING VIRAL THREATS**

The responsibility of having the opportunity to develop the world's most comprehensive One Health surveillance initiative to date was not taken lightly. Thus, we made a commitment to using a collaborative, cross-disciplinary, multi-pronged strategy consisting of concurrent human and animal surveillance, virus detection and discovery, and risk characterization paired with human behavioral and ecological investigations to explore virus sharing between animals and people and improve the world's understanding of the transmission dynamics that drive viral pathogen spillover, amplification, and spread. As a prerequisite, large-scale investments in surveillance capabilities and laboratory strengthening were made to help to establish or improve disease prevention, detection, and response systems in some of the world's most vulnerable locations for emerging infectious diseases. Our discoveries, insights, and lessons learned over the last 11 years have helped inform global research agendas, set new standards in zoonotic disease surveillance, enhanced laboratory capacity, expanded One Health training and education opportunities, and informed health policy and disease intervention strategies for achieving global health security.



## VIRUS DISCOVERY & CHARACTERIZATION

The PREDICT project established a network of partnerships in 36 countries and strengthened the virus detection capacity of 67 collaborating labs. In these labs, we used consensus polymerase chain reaction (cPCR) as a tool for virus discovery, a technique ideal for detecting both known and new viruses in a large number of samples while remaining cost effective and feasibly implemented, even in resource-limited settings. Our in-country laboratory network performed 86% of all testing, an enormous feat considering >1.3 million tests were conducted. Together, we identified 1,173 unique viruses in wildlife, domestic animals, and humans. Of these, 958 were new viruses previously unknown to science, 215 were known viruses.

## PIVOTAL DISCOVERIES

- A new ebolavirus, Bombali virus, in free-tailed bats in Sierra Leone and Guinea: this discovery marked the sixth identified ebolavirus to-date and is the first detection of an ebolavirus before disease had been reported in humans or animals.
- A new MERS-like coronavirus in an insectivorous bat from Uganda: as MERS is a significant zoonotic pathogen with high potential to cause severe disease in humans, we investigated the new virus' ability to infect human cells and determined that it does not likely pose a threat to human health. However, this discovery does highlight the role bats play as evolutionary hosts to a diverse range of coronaviruses, some of which are closely related to viruses that cause human disease.
- Ebola virus (EBOV) in a bat in Liberia >99% similar to the EBOV strain that caused the 2013-2016 West Africa Ebola epidemic: since the definitive animal host(s) of EBOV remains unknown, this discovery is an important step towards understanding the natural reservoir(s) of this deadly pathogen.
- Marburg virus (MARV) detected in fruit bats Sierra Leone >2,400 km from the nearest, previously known MARV-positive site: this discovery has brought to light the wide-ranging distribution of this deadly filovirus, allowing public health authorities in West Africa to include this virus within standard surveillance plans and enabling clinicians to add it to differential diagnosis lists to ensure rapid identification of the disease.

## HIGH-RISK INTERFACES

The conditions where people live, learn, work, and play can all have an impact on one's health, well-being, and livelihood. An interface is a point of connection between different systems or organisms. The animal-human interface is the point where people and other animals (either domestic or wildlife) come into contact. Within the context of disease transmission risk, the interface is the epidemiologic point of contact that enables movement of a pathogen from one species to another, often into vulnerable human communities. The PREDICT Consortium collected samples from people, wildlife, and domestic animals at high-risk interfaces for disease emergence and investigated the social dimensions and human behaviors and practices that drive viral spillover and spread.

Learn more in the **Special Feature: What is the Wildlife-Human Interface?**

## EBOLA HOST PROJECT

In 2016, USAID and the PREDICT Consortium designed and implemented the Ebola Host Project (EHP) – the most comprehensive search for the animal origins of ebolaviruses and other closely related viruses since Ebola disease first emerged in Africa in 1976. EHP succeeded in revolutionizing our understanding of these viruses and changed the map of their distribution across Africa. Our efforts led to the several landmark discoveries in bats, including: an entirely new species of ebolavirus (*Bombali ebolavirus*) in Sierra Leone and Guinea, *Zaire ebolavirus* (EBOV) in Liberia, and Marburg virus in Sierra Leone. These discoveries serve as frightening reminders that the cause of the 2014 West Africa Ebola epidemic and other lethal filoviruses continue to lurk at wildlife-human interfaces, with ongoing opportunities for re-emergence and potential for outbreaks with even higher tolls in human suffering.

Learn more in the **Special Feature: The Ebola Host Project - Preemptive Detection of Emerging Disease Threats**

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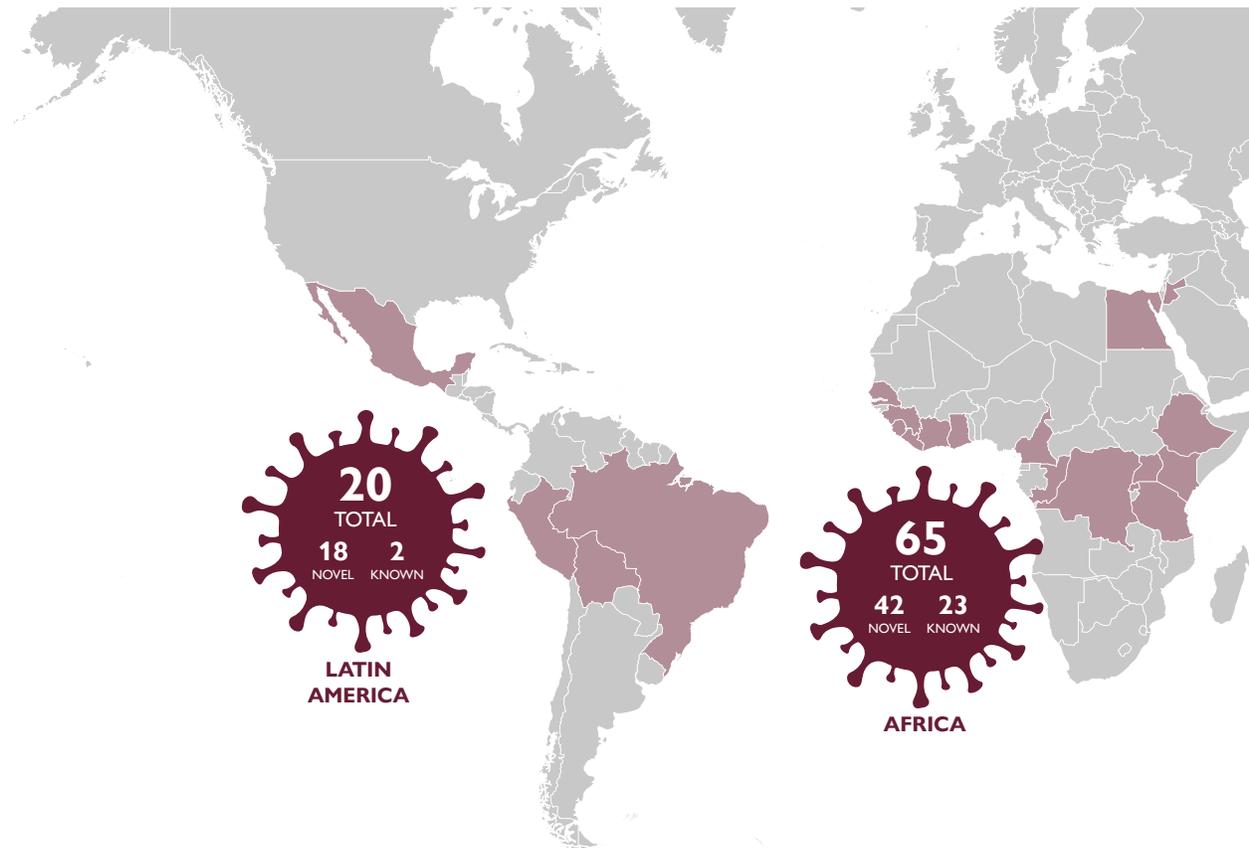


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## ADVANCING THE WORLD'S KNOWLEDGE OF CORONAVIRUSES

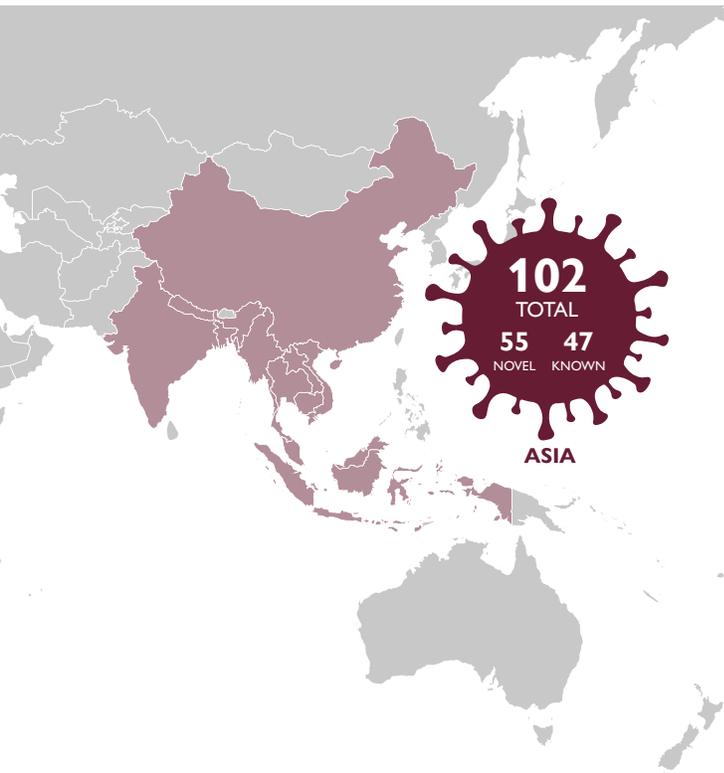
How does a virus related to ones that cause the common cold give rise to the most severe pandemic in the last 100 years? Recently emerged coronaviruses, such as SARS and MERS, are responsible for devastating epidemics, and COVID-19, which emerged in late 2019 unleashed a pandemic of biblical proportions. What do these viruses have in common, how do they emerge, what causes them to spread so rapidly following spillover? All three of these newly-discovered viruses are known or suspected to have evolved in a wild animal; are capable of infecting multiple, diverse hosts; and are suspected to have spilled over into people from animals, likely as a result of human behavior, often passing through an "intermediate" species that has close contact with humans.

Through our work and that of colleagues researching coronaviruses, we know that this group of viruses is well suited to spillover into new species and able to infect and even adapt to new hosts, characteristics common to pathogens that pose a heightened threat to health security. For over 10 years, PREDICT teams around the world worked to identify and characterize coronaviruses, searching for them in hotspots with intensive interfaces, such as live animal markets, caves where bat guano is harvested, and communities that border wildlife habitats. We advanced the world's knowledge of coronaviruses, detecting 177 coronaviruses in animals and people. Of these, 113 were coronaviruses previously unknown to science. As a result, the coronaviruses we detected have been used by other scientists to develop countermeasures, to test the potency of anti-viral drugs, and to help in the rapid assessment of the only antiviral currently in use for COVID-19 patients.



In early 2020, in response to the rapidly evolving novel coronavirus outbreak now known as COVID-19, PREDICT-trained scientists and our network of laboratories quickly mobilized, rapidly detecting and isolating the virus in their home countries before specific assays were broadly available. These leaders in One Health shared their knowledge and expertise to inform outbreak response strategies in the earliest stages of this pandemic, often enabling rapid action by public health systems.

Prior to COVID-19, our scientists provided guidance for policy makers and international institutions on reducing the risks of spillover from animals and spread among humans, working with the United Nations, World Organization for Animal Health (OIE), the International Union for Conservation of Nature (IUCN), and the World Bank. We also developed equitable approaches to reduce the epidemic and pandemic costs that coronaviruses and other emerging threats pose. These efforts include facilitating partnerships with particularly at-risk communities, those at the frontlines of spillover and emergence, working with high-risk individuals vulnerable to infection through their occupations and livelihood activities, and designing innovative strategies for reducing risks and changing human behavior for safer interactions with wildlife known as potential virus hosts.



**Number of novel and known coronaviruses detected through PREDICT project surveillance (2009-2020) by region. Numbers across regions do not total as some viruses were detected in more than one region.**

## LIVING SAFELY WITH BATS

Given the importance of bats to ecosystems, as well as the preponderance of viruses with zoonotic potential that reside in them, we worked with partners in social science to develop a communications intervention strategy, centered on human-bat risk reduction and behavior change. Together with our One Health team, we investigated the most culturally aware, feasible, and effective intervention styles and selected a moderated picture book as the appropriate tool. Following the discovery of a new ebolavirus in bats in Sierra Leone, we worked closely with USAID and partners and developed the communications plan that incorporated these outreach materials, to ensure a well-coordinated effort with government and community stakeholders. Our resulting resource, *Living Safely with Bats*, is well-received tool that appears to be effective and appropriate for risk reduction for all bat-borne viral threats, especially those from filoviruses, such as Ebola, to coronaviruses, including SARS-related and MERS-related coronaviruses. This resource has been translated into 12 languages and put into practice at national and community levels in many countries in Africa, Asia, and beyond.

Learn more in the *Special Feature: Living Safely with Bats*

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PHOTO: PREDICT INDONESIA

## EXPLORING RISK AT THE FRONTIERS OF EMERGENCE

In caves in South and Southeast Asia, several species of bats roost and interact in enclosed spaces, enabling a microbial exchange that is otherwise not very common in natural settings. PREDICT and other scientists have detected multiple coronaviruses and documented ideal conditions for switching of hosts, that might be conducive to enabling human infection by these viruses. People visit these same caves, harvesting bat guano to sell or use as fertilizer for crops and gardens, putting themselves at risk of infection, perhaps unaware that their very livelihood centers around a high-risk interface for disease emergence.

A wide range of different viruses detected during PREDICT were found in animals that were hunted or sampled near people's homes and in and around their farms and fields. The viruses detected from four high-risk groups (coronaviruses, flaviviruses, paramyxoviruses, and influenza viruses) were more likely to be observed in animals sampled during the wet season, critical information for improving the probability of detection for cost effective surveillance efforts, as well as targeting of interventions. By using machine learning models of virus sharing among animal species, we helped identify viruses that could

have a higher potential to infect people. Through these models, we found that coronaviruses have the ability to infect a greater number of species than viruses from any other group we investigated. Our data also show that bats, followed by rodents and shrews, are at higher risk for shedding viruses, especially coronaviruses, when compared to other wild mammals. Additional investments are needed to better understand the ecological and epidemiological features of bat-borne coronaviruses, especially the specific genetic features that could inform on their potential to infect people.

Our risk-based approach to One Health surveillance, focused on high-risk interfaces for disease emergence, allowing us to identify several animal-human interfaces with appropriate conditions for viral spillover, as well as control points for interventions. Live wild mammals in the animal supply chain, as well as live wild mammals sold at markets, had significantly more viruses than mammals sampled at other high-risk interfaces across the scope of PREDICT surveillance. Wildlife supply chains, including markets, represent a critical control point for needed interventions, as the conditions present at this particular interface include all of the necessary ingredients for virus evolution, amplification, and spread, the recipe for another pandemic.

Further, using serological techniques, we revealed previous pathogen exposure in at-risk populations, including those working in the wildlife value chain. Our data provide additional evidence for under-reported and unrecognized spillover events, events that are likely more common than we realize.

These findings shed light on where and how the next Disease X could spillover. Equipped with this knowledge we can better target surveillance on specific virus groups through cost effective efforts focused on at-risk human and animal populations. By using new technologies and tools, such as more rapid and sensitive molecular tests, safer and more humane approaches to sampling, additional investigations into the human behaviors driving emergence, and further advances in modeling and analytics, the PREDICT Consortium provided the data necessary to begin to identify viral threats and stop spillover in advance of the epidemics that threaten our very existence.



PHOTOS: PREDICT INDONESIA

## FOREST TO TABLE

Wildlife supply chains are complex and diverse networks that involve the removal of wild animals from their natural habitats. These animals then enter a trade network spanning a mosaic of human-dominated landscapes, often from forests and sparsely populated rural areas to dense urban markets, sometimes across borders. We focused behavioral and biological surveillance efforts on a number of wildlife supply chains involving bats, rodents, and non-human primates intended for human consumption in Africa and Asia to gain insights into the role of the wildlife trade on the emergence of viruses of pandemic potential. We explored several points of contact between wildlife and humans along these supply chains to assess the risk of viral transmission at their respective animal-human interfaces. Our findings reinforce the need for wide scale policy and human behavior change to reverse the ever-increasing trend of wildlife-human contact fueled by habitat encroachment and the harvest and trade of wildlife species.

Learn more in our **Special Feature: Forest to Table - The Wildlife Value Chain**

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PHOTO: NIGEL WALKER

## PREDICTING SPILLOVER

The PREDICT project's vision was bold and ambitious – to build capacity, gather data, and conduct surveillance in wildlife and people at critical high-risk interfaces so we could better prepare for and ultimately prevent pandemics. The goal was to disrupt the chain of disease transmission, snuffing out an outbreak before the first case amplified into a local epidemic and then spread internationally. But to stop spillover you have to know when, where, and how it will happen; you not only need diverse types of data but new approaches to analytics and modeling in order to forecast outbreaks.

We combined field data from our teams around the world and developed mathematical models to iteratively refine surveillance targets and improve the efficiency of virus discovery efforts. We worked collaboratively with our in-country partners to train and support their capacity for risk analyses and to make the tools, analytical products, and data outputs available to national decision makers.

### KEY INSIGHTS:

- Global environmental change plays a major role in disease emergence.
- Zoonotic disease spillover risk is greatest in tropical regions with high levels of biodiversity, expanding human populations, and rapid ecological change.
- Four key factors underpin disease emergence: land use change, wildlife diversity, and livestock and human population density.
- Bats, rodents, and non-human primates were predicted to host a high number of zoonotic viruses, though we identified viruses in 196 species of mammals that were previously unknown virus reservoirs.
- Within China, southwest and southern China in particular are evolutionary hot spots for bat coronaviruses.
- We can effectively predict and map the risk of disease spread and identify epidemic control points, critical intelligence to rapidly contain and prevent another pandemic.
- It is also possible for a single evidence-based intervention to reduce spillover risk for multiple viruses.
- Pandemic mitigation measures, such as direct forest protection payments, could achieve a 40% reduction in risk, and pandemic prevention costs over a 10-year period would only equal ~2% of the global costs of the COVID-19 pandemic.

By working together with our network of global partners, utilizing data collected by our One Health teams around the world, and by pioneering new analytical strategies and open-source tools to analyze the risk of disease spillover, amplification, and spread, we pushed the field of virus forecasting forward. We envision an even brighter future, one in which One Health surveillance networks continue to expand globally with the support of national leadership and in which data from surveillance and discovery efforts are collected in near-real time, then shared with local modeling and analytical teams in public health systems to refine surveillance and to develop effective early warning systems for pathogen spillover.

## ONE HEALTH OUTBREAK RESPONSE

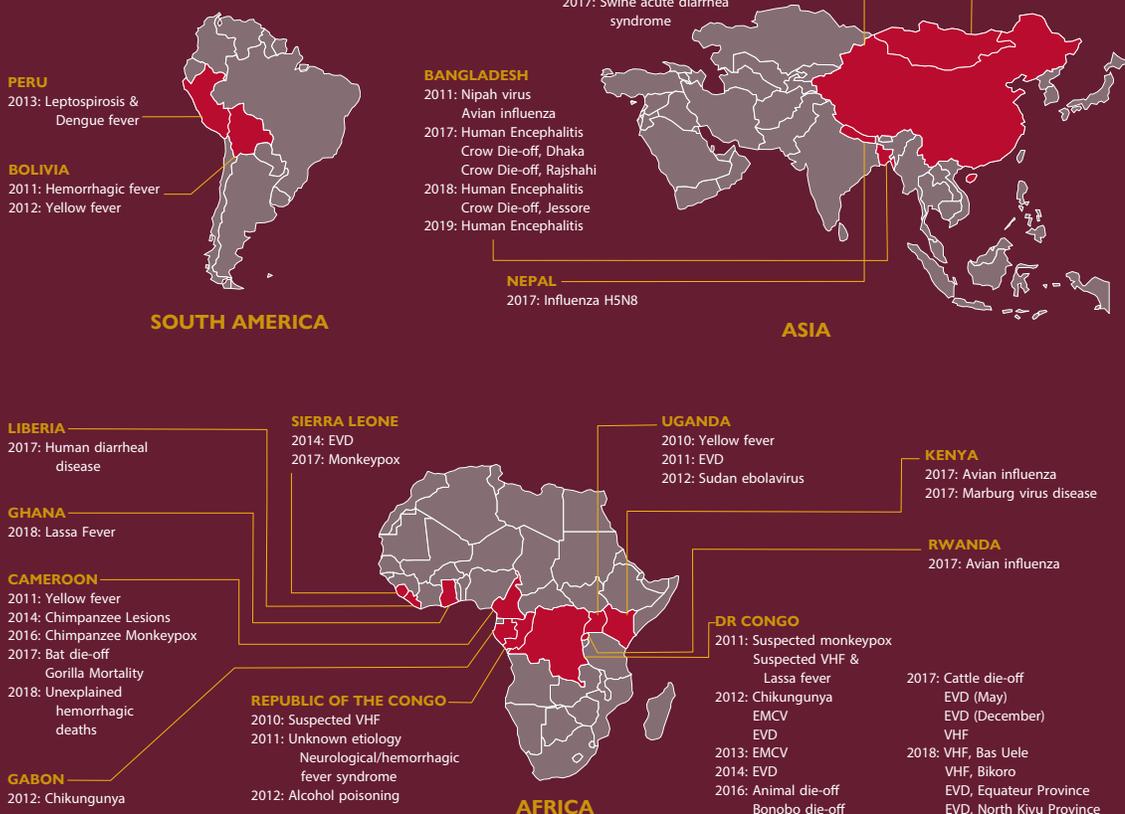
Even before COVID-19, between 2010 and 2019, PREDICT teams provided critical support to governments and international organizations during 53 outbreaks in 16 countries, including outbreaks of Ebola virus disease and viral hemorrhagic fevers, animal and bird die-offs likely to have zoonotic origins, and avian influenza epidemics. PREDICT's outbreak response strategy incorporated the One Health approach at every step, as many outbreaks were driven by pathogen spillover from animals to people. At the request of governments, our teams provided critical assistance (diagnostic support, provision of supplies and personal protective equipment, sample collection assistance) and conducted disease investigations to help tackle outbreaks affecting human, domestic animal, and wildlife populations at their source.

In addition, we worked with our partners to strengthen outbreak response capabilities. We

evaluated data and information sharing (in particular the reporting of Salzburg metrics for One Health surveillance), conducted outbreak simulation workshops, and developed a high-resolution mathematical modeling framework that simulates the spread of an outbreak and informs on high-risk areas for targeted and more effective control of epidemics.

These capabilities were put to the test in 2020, as our PREDICT-trained network jumped into action early in 26 countries, often representing some of the first responders working to first identify, then control, the newly emerging coronavirus as it suddenly spread across the globe. PREDICT partner labs detected some of the first cases of COVID-19 in their countries before a specific assay targeting the novel virus was available. These teams provided essential guidance and technical assistance to ministry partners and planners reacting to rapidly rising case numbers. This talented and proficient workforce joined emergency operations centers, led contact tracing efforts, developed risk communication strategies, and ultimately saved lives.

### PREDICT OUTBREAK SUPPORT



## STRENGTHENING A WORKFORCE & SYSTEMS TO ADDRESS 21<sup>ST</sup> CENTURY HEALTH CHALLENGES

One of PREDICT's greatest legacies is the people and the systems our project worked to support and strengthen. Professionally implementing a One Health approach to disease surveillance requires a well-trained, technically skilled, multidisciplinary, and collaborative workforce. Surveillance teams need the knowledge and capabilities to safely and humanely collect samples from animals and people, conduct the laboratory tests that identify a virus and its corresponding health risks, and explore the social and behavioral factors associated with viral spillover and spread. We collaborated with communities and governments at the local, national, and regional levels and designed and delivered training in One Health skills for both the current and future workforce, essential competencies

to prevent and respond to pandemic threats. We invested in the infrastructure required for successful surveillance and virus detection and tailored a curriculum and training program covering 19 One Health-related topics critical for project implementation and longer-term sustainability.

By leading the largest globally operational One Health project to date in terms of topical and geographic scope, we worked with partners to shift from largely conceptual interest in multisectoral collaboration to implementation and institutionalization of One Health. Our capacity building efforts spanned domains and silos and impacted many facets of existing health systems, including individuals, organizations, laboratory networks, governance structures, regulatory bodies, and policies. In just 11 years, we successfully trained, supported, and networked >6,000 wildlife, veterinary, and human health professionals from local, subnational, and national levels and facilitated knowledge-sharing and ongoing working relationships, breaking down historical barriers between sectors and disciplines.

## TRAINING IMPACT

TOTAL TRAINED  
**>6,000**  
INDIVIDUALS

(**19%**)  
STUDENTS

**41%**  WOMEN  
**59%**  MEN



**20,341**

INDIVIDUAL TRAINING MODULES  
COMPLETED BETWEEN 2014-2020

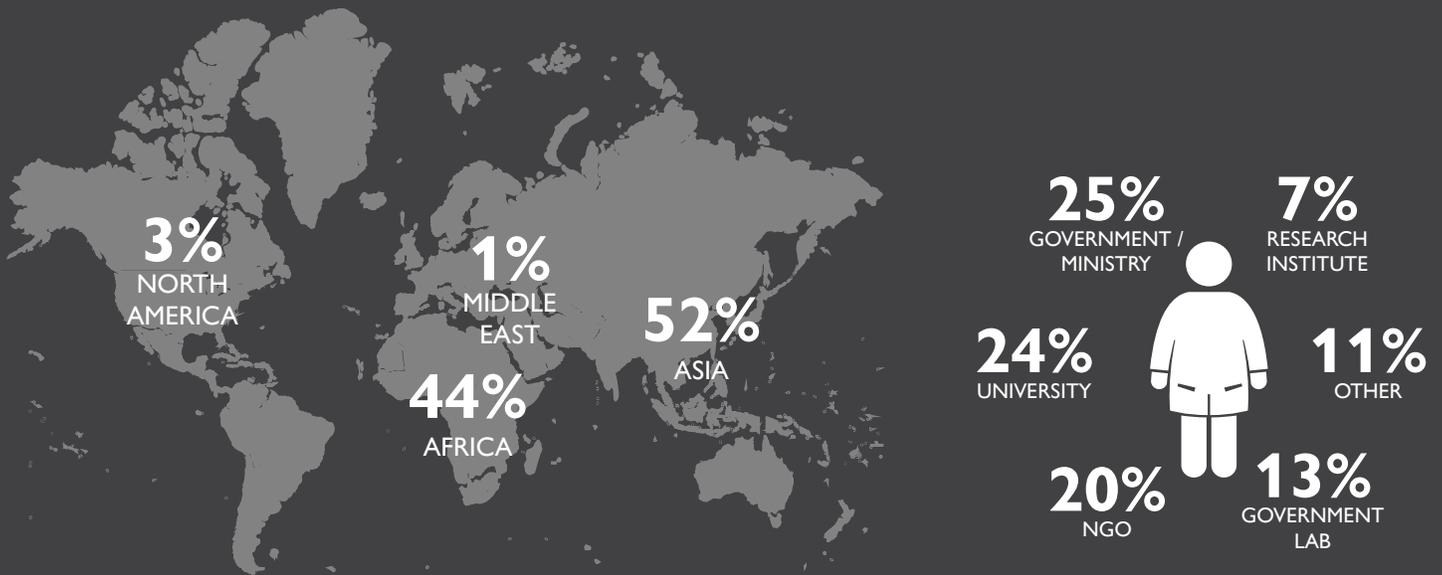


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Our work helped shape systematic changes that will make early warning and detection of disease threats from wildlife routine in national and subnational preparedness. We engaged and supported national mandates and global initiatives, seeking improvements in domestic financing and paving the way for new regulations, guiding frameworks, and policies. As a result, we are leaving behind more durable structures and systems, active and functional One Health platforms, and greatly strengthened multidisciplinary partnerships and networks.

In addition, after more than a decade of putting One Health in action, new leaders have emerged from our project, talented beneficiaries of years of intensive training, networking, and on-the-job experience at the frontlines of disease emergence. These leaders are taking the helm; integrating the One Health approach into global health security initiatives in their own institutions, countries, and regions; and continuing to put One Health in practice in their work.

Together, we have catalyzed positive change for development and instilled best practices for world class science and disease surveillance globally. In our pandemic era, the necessity for multisectoral involvement to achieve health security is increasingly obvious. New threats will continue to emerge from wildlife due to human behavior, causing disease and destruction. Meanwhile, wildlife health and disease surveillance remains massively underpowered, both in human resources and in financial investments, compared to domestic animal and public health surveillance systems. Despite the progress made by PREDICT, there are still major obstacles standing in the way of a safer and healthier future. We need further commitments and investments in One Health to continue approaches pioneered by this project, approaches that integrate disease surveillance in animal and human populations and that incorporate a holistic approach to capacity strengthening.



Training summary does not account for distribution of individuals trained early in the project in Latin America.

# TOWARD A HEALTHIER FUTURE

Continued evolution of the One Health movement is fundamental to our forward progress as a society. Demand for animal-based protein and intensifying livestock production are still major drivers of shared diseases between animals and people, especially when combined with human population growth and landscape change that drive increased contact between people and animals. It is no wonder that zoonotic infections place an enormous burden on society with a disproportionate weight on the world's livestock keepers. However, "Disease X", the novel as-yet-undiscovered infectious disease that could threaten our very existence, will most likely have wildlife origins, and this risk is greater than ever.

The human footprint can be found now in every corner of the planet. Viruses in wild animals are therefore less likely to stay within the confines of their evolutionary hosts. Disturbance of natural ecosystems has altered disease dynamics and caused increasing movements and redistribution of wildlife with their ever-increasing need to accommodate and adapt to how humans are changing the world. Wild animals have declined with respect to every relevant aspect of their existence, in terms of abundance, numbers of species, genetic diversity, and sheer biomass.

Disease regulation is a process inherent to intact

ecosystems. Declines in the quality of natural habitat due to deforestation, development, and conversion to cropland not only facilitate disease transmission by increasing movements of animals, but also simultaneously create more opportunities for animal-human interactions. Similarly, exploitation of wildlife through hunting and the wild animal trade creates close contact, crowded conditions, and movement of animals that further facilitate animal-to-human disease transmission. Wild animal species that are in decline because of habitat loss and exploitation, as well as those that are especially adaptable to human encroachment and even able to live in and around people's homes, have been shown to share more viruses with people. Transmission of a virus with pandemic potential is an extremely rare event, but if epidemiologic settings that select for a pandemic virus are increasingly common, we are all at heightened risk.

Over the past half century in particular, the natural balance has shifted. Industrialization, agricultural development, and globalization have improved human well-being and contributed to economic development, but the risks associated with ecosystem degradation and emerging infectious diseases are an unintended and as yet unmitigated outcome of our actions.



With development and advances in technology and associated changes to lifestyles, we seem to have started down a path on which we assume our health is independent of the health of the planet and the rest of its inhabitants, perhaps thinking that we are somehow insulated.

But the COVID-19 pandemic reminds us that our fate is not independent of nature. We need immediate action to preserve biodiversity, conserve and restore ecosystems, and investments in wildlife health to ensure sustainability of our own existence. This pandemic also reminds us that we are not alone. An animal-human interaction anywhere on the planet can affect us all if that interaction enables disease transmission of a pandemic threat. A virus transmitted among humans anywhere in the world can still move across borders, undetected in the earliest stages of a pandemic.

When we can travel around the world in less time than it takes for most viruses to cause disease symptoms in humans, the potential for the rapid escalation from a spillover event to a pandemic remains a global concern. Unless we reverse current trends over the course of this century, the rate that new microbial threats emerge will continue to accelerate due to growing socioeconomic and demographic factors, largely driven by the world's increasing population and interactions with animals. Success in preventing pandemics and the uncontrolled spread of epidemics requires thinking and acting differently. Revolutionary advances in health science and technology have made it possible to close the knowledge gap and discover what viral threats exist, but we must use these data and newly-

developed tools to actively prepare for and prevent pandemics.

The information collected by the PREDICT Consortium should have lasting impacts on the world well beyond the timescale of the project. Our findings raised the flag for awareness of the rich virus diversity available for human infections, especially high-consequence pathogens, such as SARS-related coronaviruses, paramyxoviruses, and filoviruses, that should be considered alongside the previously-known influenza risks. We identified high-risk human behaviors at interfaces facilitating viral transmission, as well as the human-induced drivers for pathogen emergence. Through demonstrated products and data repositories, PREDICT has provided a vast resource of new, open access material for integration into future epidemiological investigations and pandemic prevention efforts.

The PREDICT Consortium has created innovative resources for policy makers to use in order to make scientifically-informed decisions when assessing the public health risk of novel viruses, including the PREDICT HealthMap site and SpillOver risk ranking web application. Our project provided the foundation and laid the groundwork for future development and better understanding of the risks posed by novel viruses of wildlife origin. We provided the structure and evidence base for globally-scaled efforts that are urgently needed to prevent and prepare for future pandemic events. If the COVID-19 pandemic has taught us anything, it is that we can't ignore the data that all point to increasing pandemic risk, and we must take informed action now to ensure global health security.



Fortunately, visionary programs, such as PREDICT, shine a light on an alternate future. Our work was inherently collaborative and cross-disciplinary, building trust among colleagues around the world with the skills, expertise, and curiosity needed to continue investigations into emerging threats. One Health networks, such as the PREDICT Consortium, can quickly face down new threats. PREDICT's One Health team engaged partners in their vision and execution, from the highest levels of government to grass roots communities. One Health professionals engaged in transformative action, equipped with the conservation-minded participatory approaches established by the PREDICT Consortium, are now our pathway toward a healthier future. As we redefine our society and economies after the COVID-19 pandemic, we must support our next generation of leaders to combat emerging threats, conserve natural ecosystems and the environmental processes upon which we all depend, and to prioritize a sustainable and equitable future for all. In the face of overwhelming uncertainty, we have the tools to prevent the next pandemic. Emerging infectious diseases are on the rise, but they do not have to define our near- or long-term future. Our

collaborative research has dramatically increased our knowledge on the best approaches for detecting and discovering viruses of high pandemic potential that can move between animals and people. The PREDICT project provided many of the tools we need to help reduce the risk of deadly spillover events and ensure pandemics like COVID-19 never happen again – we just need to use them. We have developed and field-tested cutting-edge approaches to detecting viral spillover in high-risk populations and pioneered methods to mathematically model viral spillover risk – powerful examples of the tools needed for the fight to prevent future pandemics. Fortunately, those that have made the advancements above are today serving as the One Health-trained workforce (scientists and policy makers who explore the intersection of environmental, animal, and human health). They are prepared for and pushing back the frontlines of COVID-19 in many countries around the world. We are living in a world at risk of pandemic threats. If we heed the lessons learned from PREDICT and put them into onward action, allowing science to inform our health planning and response, we can look forward to a safer future for all.





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## PART ONE



### EXECUTIVE SUMMARY

*The Pandemic Era*



### CHAPTER 1

*One Health Surveillance for Emerging Viral Threats*



### SPECIAL FEATURE

*What is the Wildlife-Human Interface?*



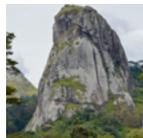
### CHAPTER 2

*Virus Discovery & Characterization*



### SPECIAL FEATURE

*Ebola Host Project: Preemptive Detection of Emerging Disease Threats*



### CHAPTER 3

*Advancing the World's Knowledge of Coronaviruses*



### SPECIAL FEATURE

*Living Safely with Bats*



### CHAPTER 4

*Frontiers of Emergence: Exploring Risk at the Wildlife-Human Interface*



### SPECIAL FEATURE

*Forest to Table: The Wildlife Value Chain*



### CHAPTER 5

*Predicting Spillover*



### CHAPTER 6

*PREDICT One Health Outbreak Response*



### CHAPTER 7

*Strengthening a Workforce and Systems to Address 21<sup>st</sup> Century Health Challenges*



### CHAPTER 8

*Toward a Healthier Future*

## PART TWO



### PREFACE

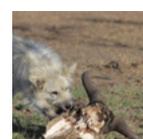
*One Health in Action Around the World*



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## PREDICT CONSORTIUM

*Implementing partners together with the ministries of health, agriculture, and the environment in over 35 countries*



