PREDICT
LIBERIA

One Health in action (2016-2020)

Finding the wildlife hosts of Ebola virus

LIBERIA
EBOLA HOST PROJECT

The 2014 West Africa Ebola epidemic, which infected over 28,000 people and left 11,000 dead, catalyzed investments to identify the animal source, or reservoir, of Ebola to prevent future outbreaks. It has been >40 years since the Ebola virus was first discovered in Central Africa and the scientific and health communities continue to search for the source. However, no standardized, large-scale, longitudinal and multi-country study targeting multiple potential reservoir hosts of Ebola virus had ever been conducted.

Following the epidemic, the PREDICT project initiated the Ebola Host Project in 2016 in Liberia along with neighboring Sierra Leone and Guinea. Our goals were to identify the wildlife reservoir for the Ebola virus that started the epidemic, to detect other related filoviruses, and to better understand the disease ecology of these filoviruses in the wild to develop risk reduction and prevention strategies.

Through the Ebola Host Project, the PREDICT project strengthened capacity for wildlife surveillance and disease detection in Liberia by training a local workforce in wildlife and domestic animal disease surveillance and in behavioral risk investigations to explore the social dimensions of zoonotic transmission in some of the country's most at-risk communities. The PREDICT project's animal disease surveillance team was the first of its kind in Liberia; the team put acquired One Health skills in practice and sampled > 5,000 animals, primarily bats and rodents. This sampling effort resulted in the first ever detection of Zaire ebolavirus in a bat in West Africa, evidence that bats are an important reservoir host for this rare and deadly virus. As a result of PREDICT project investments, this highly skilled team is now well positioned to continue contributing to disease surveillance, detection, and response and provides a critical but previously absent epidemiological component to Liberia's public health surveillance system. Among those trained in core One Health skills were two Forestry Development Authority (FDA) personnel, a critical government partner institution for sustaining these capacity gains and progressing on Liberia's journey towards self reliance in the health sector.

The PREDICT project also promoted the One Health approach within the public health sector by strengthening collaborations with the Ministry of Agriculture, Food and Agriculture Organization of the United Nations (FAO), National Public Health Institute of Liberia, and the Ministry of Health. In Liberia, the PREDICT project is viewed as an important contributor to national health security making direct impacts on One Health and zoonotic disease surveillance systems. Our team supported the operationalization of the One Heath approach in-country and participated in the country's monthly Surveillance Technical Working Group meetings under the One Health Coordination Platform. These linkages provided our team the opportunity to raise wildlife disease considerations and engage with the environment, forestry, health, and agriculture authorities on potential surveillance and monitoring strategies, some leading to the formation of multisectoral investigation teams. The inclusion of wildlife monitoring in the National Animal Disease Surveillance Plan – formally identifying wildlife information as a key source for the surveillance network - and National Action Plan for Health Security represent major successes for One Health surveillance in Liberia. In addition, the PREDICT project's involvement in Liberia's One Health Coordination Platform helped to raise attention to other relevant drivers and interfaces for disease emergence such as the wildlife trade.

LOCAL PARTNERS

- ArcelorMittal (AML)
- Food and Agriculture Organization of the United Nations (FAO)
- Forestry Development Authority (FDA)
- Ministry of Agriculture
- Ministry of Health
- National Public Health Institute of Liberia (NPHIL)
- Society for Conservation of Nature of Liberia

>30

DEVELOPED the One Health Workforce by training more than 30 people in Liberia.

>5.3K

OPERATIONALIZED One Health surveillance and sampled over 5.3K animals and people, helping minimize the spillover of zoonotic disease threats from animals into human populations.

LABORATORY STRENGTHENING

· National Public Health Institute of Liberia
· Columbia University Center for Infection & Immunity

31,120
TESTS

Global Health Security Agenda
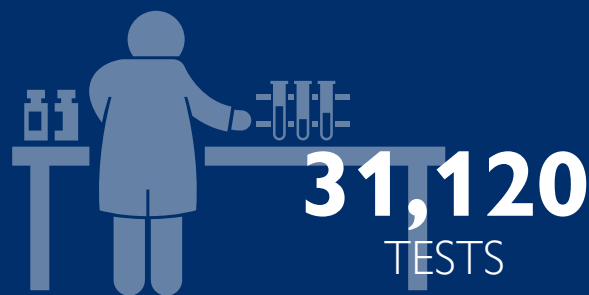
ACHIEVEMENTS

- Built the first-of-its-kind wildlife surveillance team in Liberia.

- Detected Ebola Zaire in a cave roosting, insectivorous bat, the first discovery of Ebola in a bat in West Africa and further evidence that bats are an important reservoir host for this rare and deadly virus.

- Conducted community outreach and risk communication campaigns balancing health and conservation goals that focused on sharing findings, raising awareness, and influencing behavior change.

- Played a prominent role in establishing and operationalizing the National One Health Coordination Platform.

- Piloted the PREDICT-developed illustrated book, Living Safely with Bats, in local communities

1
KNOWN

DETECTED 1 unique virus, *Zaire Ebolavirus*, in animal populations.

ONE HEALTH SURVEILLANCE

In collaboration with in-country partners, an extensive surveillance program was implemented in Liberia to successfully identify the animal source and reservoir of Ebola virus and other closely related filoviruses (ebolaviruses and marburgviruses). At multiple sites across the country, biological specimens were safely and humanely collected from 5,387 animals (5,182 bats and 205 rodents).

VIRUS TABLE

VIRAL FAMILY	VIRUS	SPECIES	SAMPLING LOCATION	TOTAL POSITIVE INDIVIDUALS
Filovirus	Ebola virus (EBOV)	Nimba Long-Fingered Bat	Gangra	1
Total				**1**

VIRUS DETECTION

In partnership between the National Public Health Institute of Liberia and the Columbia University Center for Infection and Immunity (CII), samples from >5,300 animals were safely tested for the presence of Ebola or other related filoviruses, along with with another priority viral family, paramyxoviruses. One virus, *Zaire ebolavirus*, was detected in a Nimba long-fingered bat, *Miniopterus nimbae*.

ZAIRE EBOLAVIRUS DETECTED IN AN INSECTIVOROUS BAT

One sample from a Nimba Long-fingered bat (*Miniopterus nimbae*) sampled in Nimba country tested positive for *Zaire ebolavirus*. This is the first identification of Ebola virus in a bat in West Africa. To confirm the finding and sequence the genome, PREDICT's team at the CII lab utilized VirCapSeq-VERT, a new tool invented at CII that improves the sensitivity

of next generation sequencing 1,000-fold. No human cases were associated with this discovery, though work continues at CII to determine if the virus detected in this bat was the same strain that caused the 2014 West African Ebola epidemic.

> *"There have been unanswered questions about the source of Ebola outbreaks. There was speculation that they may have originated from bats, but there was no direct evidence."*
> **–SIMON ANTHONY**
> PREDICT Pathogen Detection & Discovery Co-Lead

Long-fingered bats of the genus *Miniopterus* are small insectivorous bats (family: Miniopteridae) that are found throughout Africa. They are an agriculturally important group, as they eat insects that damage crops. These bats are typically found in forests, caves, and mines and are not known to roost in people's homes or dwellings, critical information for reducing

risk of contact between bats and people and for preventing Ebola virus spillover.

Following the detection of the virus, the PREDICT team worked with the Government of Liberia to proactively develop a communication and public engagement strategy. The Ministry of Health and National Public Health Institute of Liberia paired the public release of the finding with a risk communication plan balancing health and conservation goals. The outreach campaign targeted communities in Nimba county and the surrounding region and was designed to raise awareness of zoonoses and risk of disease transmission while minimizing unintended consequences and harm to bats.

IDENTIFYING BEHAVIORAL RISKS FOR VIRUS SPILLOVER & SPREAD

The PREDICT team examined the social dimensions driving viral spillover and spread by investigating human and animal interactions, and exploring knowledge, attitudes, and practices associated with disease transmission risk. Our team designed a study and helped develop a standardized questionnaire designed for use in all three Ebola Host Project countries. Goals of the study were to: 1) identify behavioral and ecological factors that could lead to the risk of viral spillover, amplification, and spread; and 2) determine potential targets for intervention based on this evidence. This questionnaire was developed to explore the different ways that people interacted with wild and domestic animals, the kinds of exposures individuals faced in markets, how they mitigated risk during high-contact activities such as hunting and handling bushmeat, and how they understood their own susceptibility to disease.

In Liberia, participants were recruited from areas affected by the 2014 Ebola epidemic and in communities where humans regularly interacted with wildlife and domestic animals (e.g. live animal/bushmeat markets), sites with a high density of species of zoonotic disease interest (e.g. bat roosts, non-human primate habitats, etc.), and control areas that had no reported cases of Ebola. These sites purposefully represented geographies ranging from urban, to rural, and pristine. We enrolled and interviewed 635 individuals, including four children, across eight counties (Lofa, Nimba, Bong, Gbarpolu, Grand Cape Mount, Grand Geddeh, Sinoe, and Montserrado).

PRELIMINARY FINDINGS

Though analysis is ongoing, our findings highlight the proximity with which many communities across the pristine-rural-urban landscape exist and interact with animals. Poultry, rodents, goats, and sheep were reported as regularly entering human dwellings, and respondents shared reports of cooking or handling recently killed rodents and ungulates. Many respondents also reported eating raw, undercooked, or smoked meats, organs, and blood – frequently rodents and ungulates. The presence of rodents in proximity to dwellings and consumption of rodents in particular presents a risk for transmission of Lassa virus, which is endemic in the region and is a recognized priority zoonotic disease.

A recurring theme that emerged in our analysis was the intractability of behavior and preference, even when tested by crisis. Respondents were asked about health-seeking behaviors for medical issues both before and during the Ebola outbreak. In general, individuals reported accessing 'formal' health services through hospitals, clinics, and health centers, though traditional care was also an important component of treatment for respondents from all geographic areas (Figures 4, 5, and 6).

When asked about the etiology of Ebola, the majority of respondents acknowledged that they did not know what caused the Ebola outbreak in their country. However, many respondents did attribute the origins of Ebola to wild animals, sick people, their bodily fluids, and domestic animal excreta (Figure 7). With regard to concerns over disease outbreaks in local live animal markets, respondents across all geographies noted a stark rise in their concern during the Ebola outbreak. In the period following the crisis, however, reported concern diminished (Figure 8).
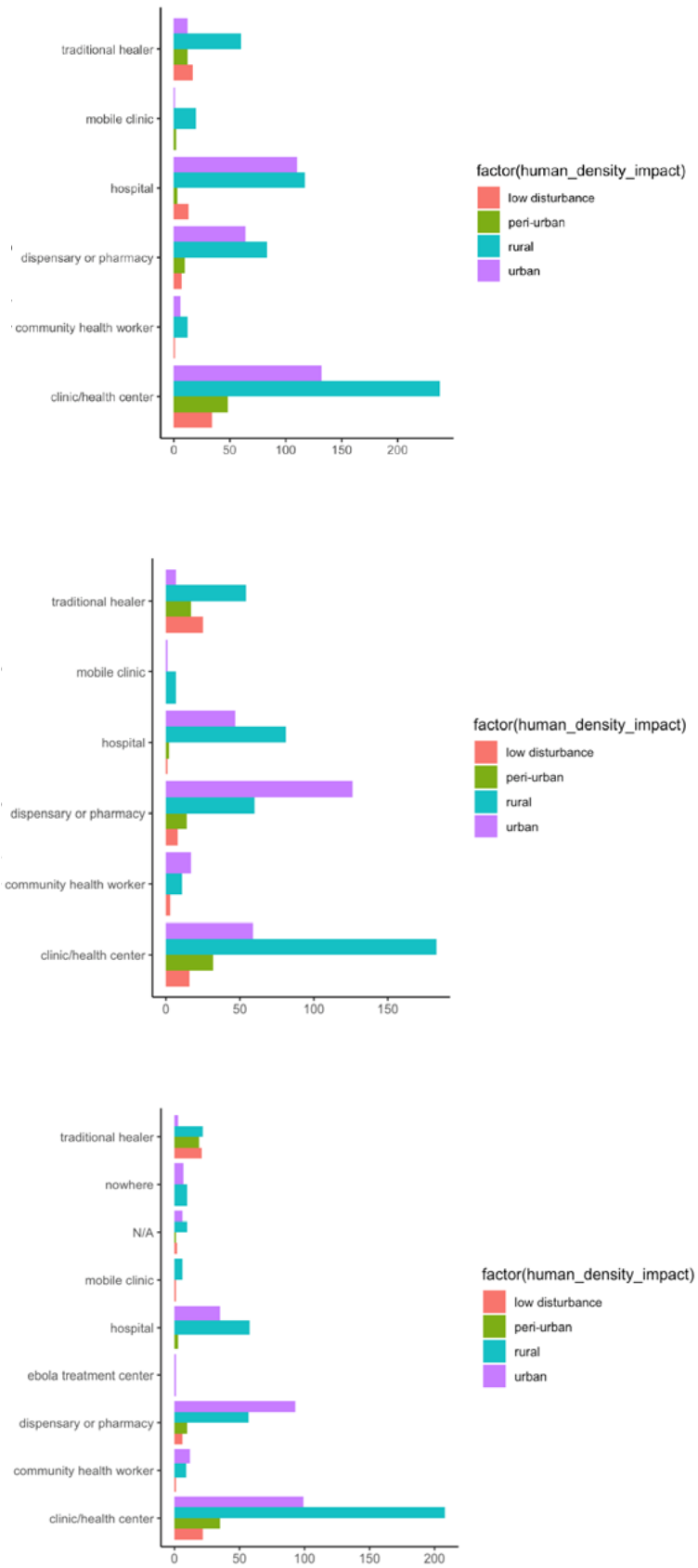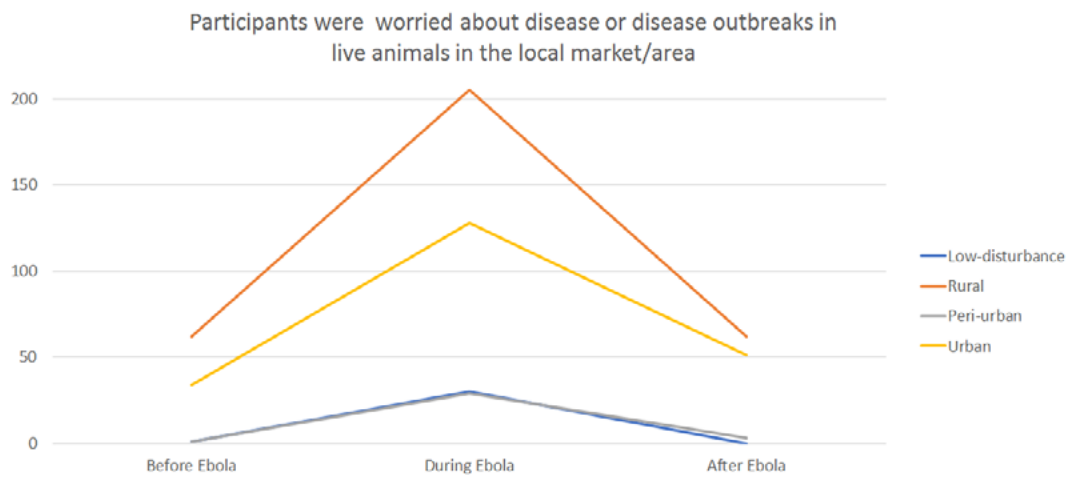

FIGURES 4-6. Where individuals reported seeking health care before (top), during (middle), and after the outbreak (bottom). Respondents were able to select all applicable options.
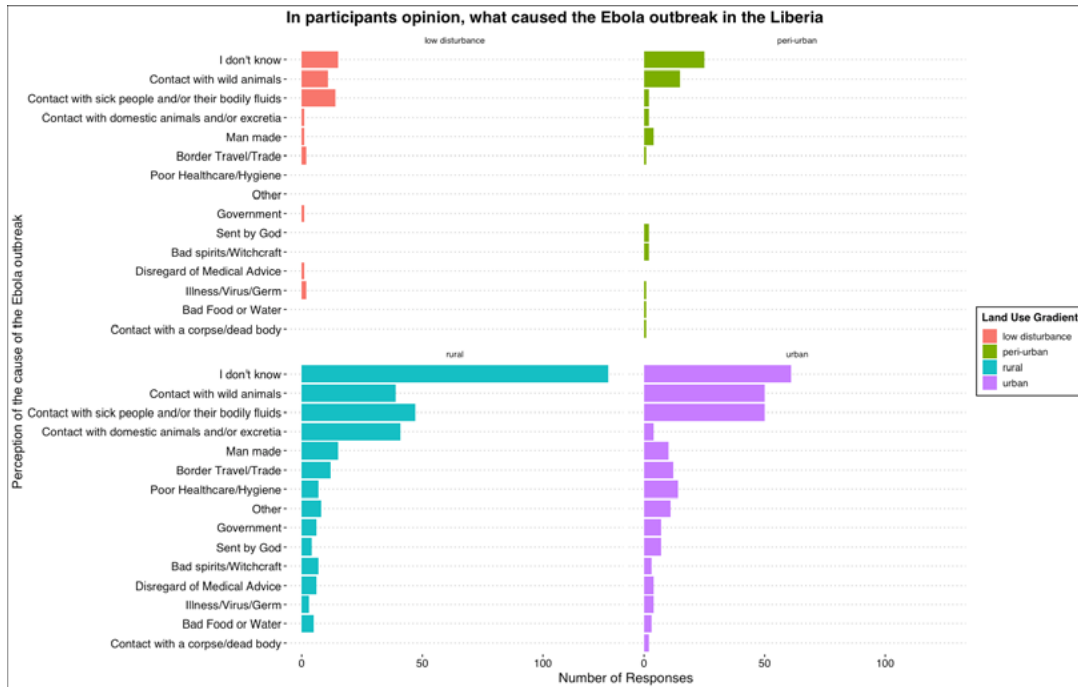
FIGURES 7. Interviewer responses on perceived cause of the 2014 West African Ebola epidemic.

FIGURES 8. Reported concern about disease or disease outbreaks in local live animal markets before, during, and after the Ebola outbreak.

COMMUNITY OUTREACH & RISK COMMUNICATION

The PREDICT project played an instrumental role in establishing the One Health Coordination Platform in Liberia, making it operational by providing technical, logistical, and moral support to the effort. In addition, our staff were involved in the development of the National Action Plan for Health Security, National Surveillance and Response plans for Lassa Fever and Influenza, and provided technical support on many zoonotic disease related topics. Further, the PREDICT team were members of the One Health Technical Working Groups since the formal establishment of the One Health Platform providing a unique perspective, especially on conservation and emerging disease risks from wildlife.

Community engagement was critical to the success of our One Health surveillance strategy. The team in Liberia performed outreach in sometimes difficult environments, explaining the importance of the project and our approach. Our team met with community leaders to answer questions and explain the project prior to engaging in fieldwork. In communities affected by the 2014 Ebola epidemic, this was no small task. Perhaps more importantly, our team revisited all of the communities where we conducted surveillance and fieldwork to share our findings and presented the PREDICT project-developed risk reduction and behavior change communications resource *Living Safely with Bats*.

Communication was perhaps never more important than following the discovery of Ebola Zaire in a bat in northern Liberia. Upon informing government partners of the discovery, the Ministry of Health decided to announce the finding to the public. There was still pervasive societal sensitivity to Ebola which had devastated the country only five years earlier. However, the Government of Liberia believed that it was important to inform the public of their efforts to identify where Ebola came from and to provide news of the discovery along with guidance on how to reduce the risk of exposure by avoiding mines and caves where the type of bat that tested positive lives. PREDICT worked closely with government partners to develop evidence-based messaging that would help reduce risk of exposure to Ebola virus without creating fear of bats.

STRENGTHENING CAPACITY

Despite extremely limited veterinary capacity in Liberia, our team leveraged PREDICT project investments in wildlife surveillance and broader One Health skills and competencies to build a strong foundation for providing a range of field, policy, and training opportunities. For example, PREDICT project partners in Côte d'Ivoire expressed an interest in strengthening wildlife surveillance capacity, and in response, our Liberia team co-led a training with the PREDICT Côte d'Ivoire team. Held at the Abidjan Zoo in June 2019, trainers from the Liberia team provided hands-on training in bat and rodent sampling to 50 participants from a range of government partners in Côte d'Ivoire. The involvement of the Liberian team also reinforced the value of cross-border collaboration on surveillance and information sharing, contributing to wider regional preparedness. Further leveraging their training on safe and humane animal handling and One Health, our team has been called on by the Liberian government to implement and provide expertise during canine rabies vaccination campaigns.

"One of PREDICT's most important achievements in Liberia was the development of the country's first surveillance team capable of safely sampling bats and other wildlife for zoonotic viruses, including Ebola. To prevent the next outbreak, whether it's Ebola or Disease X, it's necessary to understand where these viruses come from. Liberia now has the ability to do that."

–DR. JON EPSTEIN
PREDICT global team & Ebola Host Project, Liberia technical lead.

In addition, the PREDICT team in Liberia was trained on One Health policy and evaluation, using their skills to review and critique a draft decision on health and biodiversity under the UN Convention on Biological Diversity (CBD). The team identified key points of relevance for Liberia and generated recommendations via a policy statement that was shared with Liberian government officials from the Environmental Protection Agency. This ultimately formed the basis of messages disseminated at the CBD Conference of the Parties and the inclusion of a clause recommending that countries conduct integrated health and biodiversity impact assessments.

PRACTICAL IMPLICATIONS

The PREDICT project changed the landscape for public health in Liberia. Our project established the first-of-its-kind wildlife surveillance team and successfully integrated into the existing public health infrastructure. In addition, our team played a major role in creating a new public health paradigm through the lens of One Health.

- The PREDICT project developed the country's first One Health surveillance team, which included wildlife biologists and field technicians able to safely sample wildlife and livestock for viral pathogens such as Ebola, and social scientists who conducted behavioral risk analysis and community outreach to reduce the risk of viral spillover from animals to people.

- Our team detected Ebola Zaire virus in a mine-dwelling bat in northern Liberia, the first time this virus had been identified in a bat in West Africa, providing important evidence that this virus continues to circulate in bats in the region.

- Following the discovery and announcement of Ebola Zaire, the PREDICT team worked closely with the National Public Health Institute, Liberia and the Ministry of Health to coordinate and implement a successful public risk communication campaign. As part of this campaign, our team developed and utilized an illustrated risk reduction and behavior change communication resource *Living Safely with Bats* for community education and provided the resource to the Ministry of Health to become part of their public risk communication toolkit.

PROACTIVE PATHOGEN DETECTION & RISK COMMUNICATION TO PROTECT COMMUNITIES LIVING CLOSELY WITH ANIMALS

The PREDICT project's support of the first wildlife veterinarian in Liberia led to critical workforce development where veterinary capacity is extremely limited. Ten field staff were trained on PREDICT project protocols on animal handling, sampling, and biosafety, and these trainings were deployed for use in extensive bat and rodent sampling efforts. The team was put to the test through intensive wildlife sampling resulting in the first ever detection of *Zaire ebolavirus* in a bat in West Africa.

In addition to continuing to shed light on the role of bats as the reservoir for high-consequence pathogens such as Ebola, the capacity of the trained wildlife disease investigation team was leveraged to provide research and management support for other zoonotic diseases, including rabies.

Liberia has embraced the One Health approach in light of the country's endemic and emerging zoonotic disease priorities, forming a One Health Secretariat with representation from human and animal health, forestry, and environmental agencies. This provides a strong platform to improve understanding of baseline risk, needs assessment for additional priority surveillance, and interventions to target high-risk activities. For example, Ebola is now included in the National Animal Health Surveillance Strategy developed in early 2019. The Ebola finding is also potentially relevant for the health and conservation of Liberia's wildlife, as other species are susceptible to Ebola virus.

Learn more here: **p2.predict.global/strengthening-health-security**

PUBLIC-PRIVATE PARTNERSHIPS TO PREVENT PANDEMICS

In 2016, when the PREDICT program initiated the Ebola Host Project in West Africa, EcoHealth Alliance (EHA), a PREDICT project global partner, was engaged in discussions with ArcelorMittal (AML), a global iron ore mining company present in Nimba County, northern Liberia. ArcelorMittal opened in Liberia in 2006 and represents one of the largest foreign investors in the country. They provide significant contributions to Liberia as an employer and also by building schools, hospitals, roads, and other infrastructure. AML approached our team about a colony of bats that was residing inside an unused exploratory mine shaft on its mining property. AML was planning to move the resident bats from the mine shaft into a new artificial cave they built within a forested area on their property. Recognizing the potential for the bats to disperse, the Ministry of Health had asked AML to screen these bats for Ebola virus before moving them. The PREDICT team worked with AML to screen these and other bats on and around the property for Ebola and related viruses. In return, AML provided support to the PREDICT team, including providing housing and meals on their property during training and subsequent sampling activities, as well as on-site training facilities (e.g. conference rooms) and logistical support including security, equipment storage, and transportation during bat sampling activities. The bat samples tested negative for Ebola, and the bats were successfully translocated to the new artificial cave. The PREDICT team returned to Nimba County several times throughout the 2016-2018 sampling period, occasionally working on AML property.

In November 2018, a bat that had been captured and sampled on AML property tested positive for *Zaire ebolavirus* – the same virus responsible for the 2014 outbreak. The result was reported to the National Public Health Institute of Liberia (NPHIL) and the Ministry of Health. When the Government of Liberia made plans to publicly announce the finding, the Director General of NPHIL and the PREDICT team met with an AML executive in Monrovia to share the finding. ArcelorMittal reaffirmed their commitment to work in Liberia. Following the finding, the PREDICT team provided technical information to AML, which is being used to develop communications for their employees and to the communities around the mining concession.

INSIGHTS ON THE GEOGRAPHIC DISTRIBUTION OF MOLOSSID BATS IN WEST AFRICA

Through the Ebola Host Project, PREDICT teams in in Sierra Leone and later Guinea detected a new ebolavirus, Bombali virus in molossid bats. In recognition of the limited data available regarding bat distribution in the West Arica region, the Government of Guinea requested assistance identifying areas in the country and greater West Africa region at highest risk for virus spillover from bats. In response, we developed a spatial distribution model to identify areas that are ecologically suitable for habitation of Molossidae bats, such as *Mops condylurus* (Angolan free-tailed bat) and *Chaerephon pumilus* (Little free-tailed bat), that were found to harbor Bombali virus.

Using PREDICT project data, our model identified areas in the region that are suitable for habitation and where the bats may be present at higher densities, resulting in increased human contact and possibly higher virus spillover risk. Tools such as this model can assist the Governments of Guinea, Liberia, and Sierra Leone to better target wildlife surveillance and community-based risk reduction activities.

Learn more here: **bit.ly/3fH56Nw**

For more information
view the interactive report at
p2.predict.global

SPECIAL FEATURES