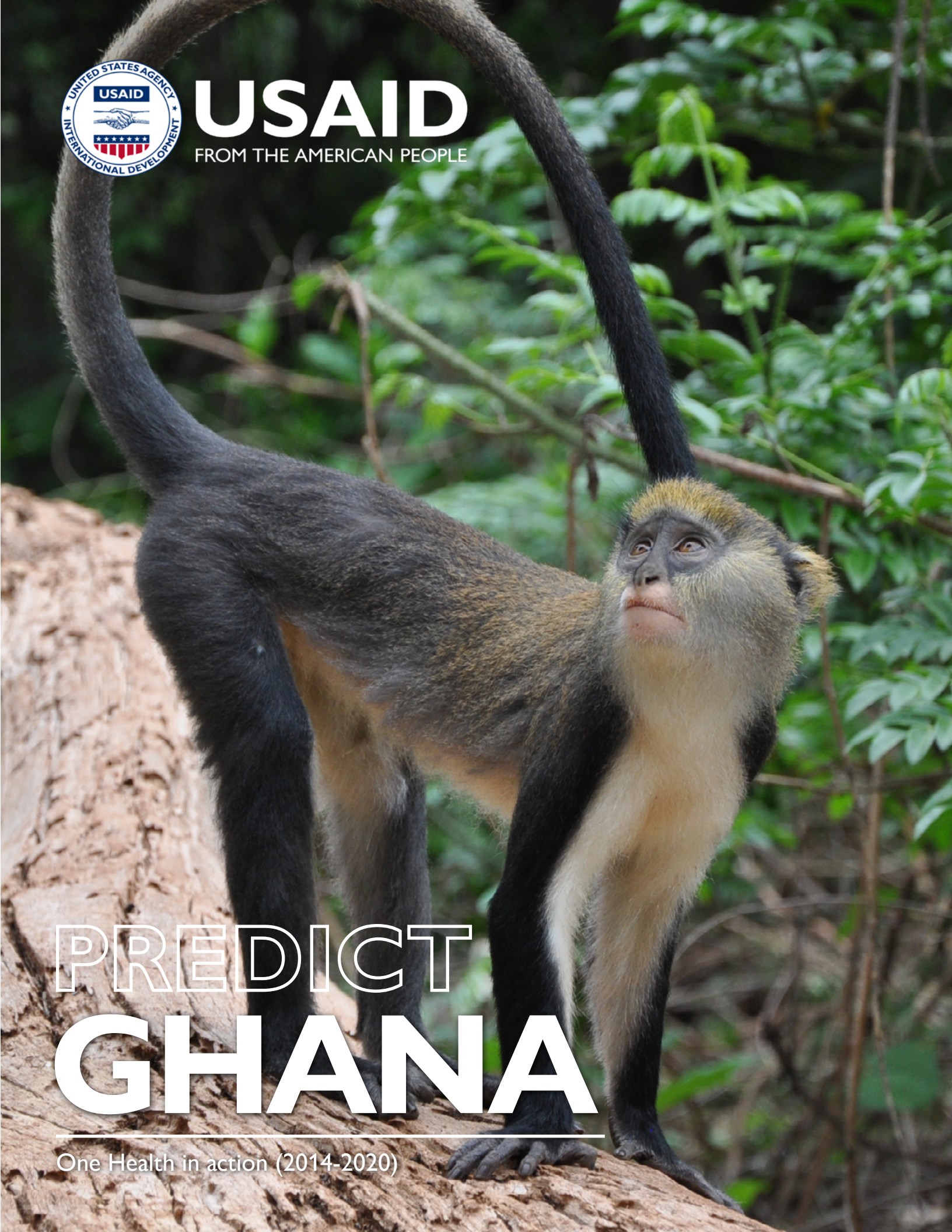

USAID
FROM THE AMERICAN PEOPLE
PREDICT
GHANA
One Health in action (2014-2020)

Using a One Health approach to enhance national health security by strengthening disease surveillance and laboratory capacities for detection, response, and prevention of current and emerging zoonotic viral threats.

GHANA

In Ghana, a rapidly growing economy and population have led to deforestation, agricultural expansion, human migration, and vibrant regional trade – all factors associated with risk for disease emergence and spread (Daszak et al. 2001). PREDICT was initiated in Ghana in 2016 to enhance existing capacities to conduct surveillance for emerging viral zoonoses of pandemic potential (filoviruses, coronaviruses, paramyxoviruses, flaviviruses, arenaviruses (humans only), and influenza viruses) at high-risk disease transmission interfaces between wildlife, livestock, and people.

PREDICT used a One Health approach to conduct disease surveillance in bat, rodent, primate, and human populations in a rural setting near the Boabeng-Fiema Monkey Sanctuary and in a highly urban setting in the capital city. In the rural communities of the Nkoranza North District, people depend heavily on agriculture for their livelihoods and come into close contact with bats and rodents in their homes and while working and hunting in their agricultural fields. Traditional beliefs and local law forbid physical harm to the monkeys in the sanctuary, which come into the village daily to enter peoples' homes, raid food stores, and feed alongside livestock in the agricultural fields. Tourists visiting the sanctuary also feed the monkeys, a practice which increases the populations' dependence on artificial food and is thought to contribute to population growth, leading to human-primate conflicts and heightened risk of shared diseases.

PREDICT also targeted for surveillance, one of the largest known urban bat roosts in West Africa, an *Eidolon helvum* colony in Accra's city center. Recent studies in Ghana suggest that *E. helvum* harbor zoonotic or potentially zoonotic viruses, including henipaviruses (Drexler et al. 2012; Hayman et al. 2008a), lyssaviruses (Hayman et al. 2008b; Suu-ire et al. 2017), and ebola viruses (Hayman et al. 2010). This is notable because *E. helvum* migrate long distances, roost in high densities in large colonies across Africa, and are hunted for consumption (Kamins et al. 2011).

In addition to sampling people in the high-risk communities, PREDICT conducted syndromic surveillance in patients presenting with acute febrile illness of unknown origin to clinics, including a large referral hospital in Accra's city center, that receives cases for most medical disasters and disease outbreaks in the country. The clinics served the communities where PREDICT conducted surveillance.

Through analysis of project data and findings, PREDICT was able to identify risks and educate communities and health professionals on behavior change and intervention strategies designed to protect people and wildlife from disease threats. When requested by the government of Ghana, PREDICT also utilized a One Health approach to assist with disease outbreak investigations. In addition, the team played a key role in activities under the Global Health Security Agenda, including evaluation of the country's strengths, gaps, and priority actions for enhancing national health security; prioritization of zoonoses of public health concern in Ghana; and development of a national One Health policy.

IMPLEMENTING PARTNERS

- 37 Military Hospital
- Ghana Health Service
- Noguchi Memorial Institute for Medical Research, University of Ghana
- United States Agency for International Development
- University of California, Davis
- Veterinary Services Department, Ministry of Food and Agriculture
- Wildlife Division of the Forestry Commission, Ministry of Land and Natural Resources

OTHER PARTNERS

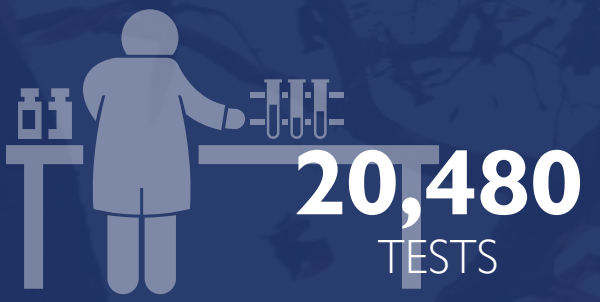
- Ghana Armed Forces
- Food and Agriculture Organization of the United Nations
- Ministry of Health Emergency Operations Center
- Ministry of the Interior National Disaster Management Organization
- NAMRU-3
- National Public Health Reference Laboratory
- Partnership for Health Care Improvement
- United States Centers for Disease Control & Prevention
- World Health Organization

DEVELOPED the One Health Workforce by training more than 60 people in Ghana.

OPERATIONALIZED One Health surveillance and sampled over 3.4K animals and people, to identify ways to help minimize the spillover of zoonotic disease threats from animals into human populations.

LABORATORY STRENGTHENING

- Accra Veterinary Laboratory
- Noguchi Memorial Institute for Medical Research, University of Ghana



DETECTED 16 unique viruses in both animal and human populations.

COL SAMUEL BEL-NONO

Country Coordinator

Retired from the Ghana Armed Forces Medical Services

"PREDICT is a versatile project that brings together disease surveillance and diagnostic laboratory networks to support the Global Health Security Agenda and One Health platform in Ghana. The project has expanded the tools and approaches to viral disease investigations and strengthened national capacities for prevention, detection, and response to zoonotic viruses."

EVANGELINE OBODAI

Human Laboratory Lead

Noguchi Memorial Institute for Medical Research, University of Ghana

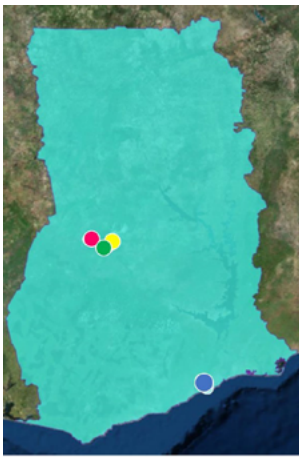
"PREDICT is directly encouraging inter-ministerial collaboration and providing the opportunity for partners to work together in the field and laboratories; directly strengthening cross-sectoral information and data sharing; and helping to enhance capabilities for early zoonotic disease detection, prevention, and response. PREDICT has been able to strengthen laboratory capacity for zoonotic disease detection in Ghana by providing a useful basic PCR tool/platform that comes in handy for screening for novel viruses."

ACHIEVEMENTS

- Expanded the scope of national disease surveillance activities in Ghana to include a focus on zoonotic viruses of major public health significance
- Strengthened national capacities to detect novel viruses that may be the cause of undiagnosed illnesses in Ghana. The Virology Department at NMIMR conducts diagnostic testing for viral pathogens in clinical cases, for the Ministry of Health/ Ghana Health Service. PREDICT virus detection protocols for filo-, arena-, flavi-, influenza, corona-, and paramyxoviruses are now included in the molecular diagnostic suite used to investigate the cause of illness for these referred cases
- Enhanced capacity for the Ghana Health Service vector surveillance system by incorporating PREDICT's protocol for safe specimen collection into the field activities and PREDICT's virus detection protocols into the suite for molecular-based assays used to screen rodent and mosquito samples for evidence of viruses of public health importance, including Ebola, Marburg, Crimean Congo Hemorrhagic Fever, Dengue, Zika, Chikungunya, Yellow fever, Lassa, and other Arenaviruses
- PREDICT Ghana's two human syndromic surveillance sites in the Nkoranza North District of the Bono East Region were recommended for designation as sentinel sites for zoonotic disease surveillance by the Head, Disease Surveillance Department, Ghana Health Service
- Enhanced national health security by playing a key role in the Joint External Evaluation of IHR core capacities, Zoonotic Diseases Prioritization Workshop, and development of the implementation plan for the Global Health Security Agenda Zoonoses Action package for Ghana
- Strengthened institutional collaboration for implementation of One Health approaches through increasing awareness of One Health at the ministerial level and contributions to development of the national One Health policy
- Implemented One Health approach to support the Ghana government in investigation of a suspected Lassa fever case

ONE HEALTH SURVEILLANCE

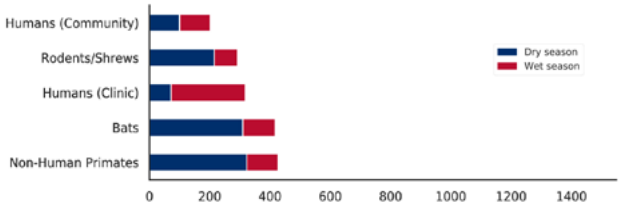
PREDICT's One Health surveillance approach was designed to strengthen capacity for detection of emerging viral threats and to improve our understanding of risk of zoonotic diseases in communities with close and frequent animal contact. Our team safely and humanely sampled wildlife (bats, rodents, and non-human primates) and people concurrently, targeting high risk populations for virus spillover, amplification, and spread in rural and highly urbanized settings in Ghana. We also conducted syndromic surveillance of patients presenting to local clinics serving the communities at our sites. Data collection and sampling was performed longitudinally over a three-year period during both the rainy and dry seasons. Species identification of bats and rodents was confirmed using DNA barcoding, a molecular-based laboratory assay.



Nkoranza North District - Community
Nkoranza North District Health Center 1
Nkoranza North District Health Center 2
37 Military Hospital

PREDICT surveillance sites in Ghana

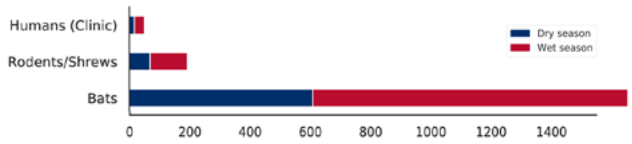
NKORANZA NORTH DISTRICT



Numbers of individuals sampled by taxa group in Nkoranza North District

Our team conducted surveillance in communities within the Nkoranza North District near the Boabeng-Fiema Monkey Sanctuary. These community members are primarily farmers who rely on extensive small-scale crop and livestock production (primarily domestic fowl, sheep, and pigs) and to a lesser degree hunting for their livelihoods. The Boabeng-Fiema Monkey Sanctuary, which draws visitors from around the world, is home to over 700 monkeys (Black and White Colobus and Lowe's Mona monkey) that interact with the communities through daily visits to the villages where they enter homes and raid food stores. The monkeys also have contact with sanctuary visitors who feed them by hand, a practice discouraged by local officials. Interspersed among the patches of sanctuary forest are cashew and mango orchards, which provide foraging habitat for a diversity of fruit bats, bringing them into close proximity to these farming communities. In addition to sampling wildlife (bats, rodents, non-human primates) and people at the villages, we conducted syndromic surveillance at two nearby health centers where we targeted patients presenting with acute febrile illness.

ACCRA



Numbers of individuals sampled by taxa group in Accra

Our team also conducted surveillance on the grounds of the 37 Military Hospital in Accra's bustling city center, which is home to one of the largest known urban fruit bat (*Eidolon helvum*) colonies in West Africa (~250,000 bats). The bats migrate long distances, congregating in their urban roosts during the dry season and migrating into the northern savannas at the onset of the wet season. The bats roost and fly over a busy transit center where people gather for public transportation. In addition to sampling wildlife at this site, we targeted patients presenting to the 37 Military Hospital, a large referral hospital that receives patients from the local community and from across the country, especially during disease outbreaks.

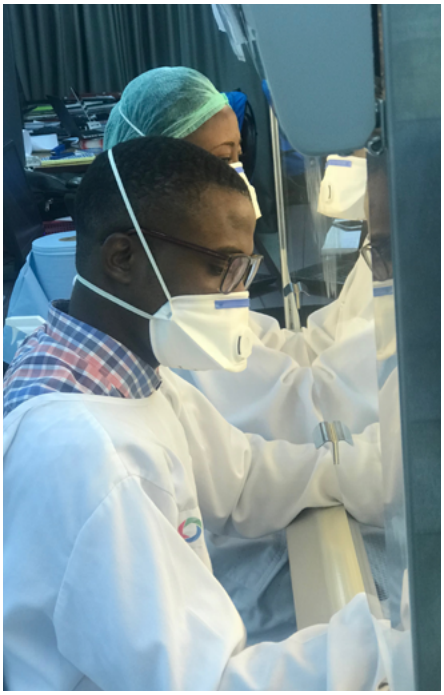
VIRUS DETECTION

PREDICT's strategy for virus detection in Ghana included screening samples using broadly reactive consensus PCR (cPCR) for five priority viral families:, including corona, filo, flavi, arena (humans only), and paramyxo families, and influenza viruses. Viruses detected via these assays were sequenced to investigate their relationship to known pathogens and samples were prioritized for further characterization via sequencing based on these results. This approach allows for detection of both known and novel viruses and improves our understanding of the potential for the virus to cause disease in humans and/or animals.

Using this strategy, our teams safely tested samples from 565 people and 1,620 wild animals. We identified both known and new viruses in bats and rodents and detected known viral pathogens circulating among people that were not monitored through national surveillance programs (see Virus Findings Table). In patients with acute febrile illness, we identified common causes of illness, including Influenza A (22 cases), Influenza B (five cases), Betacoronavirus 1 (OC 43) (four cases), Human Parainfluenzavirus 2 and 3 (one case each), and Mumps (one case). Influenza A virus (two cases) and Human Coronavirus 229E (one case) were also detected in individuals through the community-based surveillance. These findings shed light on viral causes of respiratory illness, which is common in the community and an important cause of mortality in the country.

In wildlife, we identified 3 new paramyxoviruses in rodents and shrews and 2 paramyxoviruses in bats. We detected several coronaviruses in bats, including a new Betacoronavirus in a Gambian epauletted fruit bat (*Epomorphorus gambianus*).

Most commonly, the Betacoronaviruses, Kenya bat coronavirus/BtKY56/BtKY55 and Eidolon bat coronavirus, were detected (81 and 77 bats, respectively). Four bats also tested positive for the Alphacoronavirus Chaerephon bat coronavirus/Kenya/KY22/2006.



NMIMR has incorporated the PREDICT virus detection protocols into its diagnostic platforms for screening samples from clinical cases with illnesses of unknown etiology

Among species of bats with detections of Kenya bat coronavirus/BtKY56/BtKY55, the percentage of positive bats was highest in *Epomops buettikoferi* (33%) followed by *Mops condylurus* (16%), *Epomophorus gambianus* (15%), *Epomops franqueti* (6%), and *Eidolon helvum* (2%). The virus was detected most commonly at the Nkoranza North District site with bats sampled at this site eight times more likely to test positive for this virus as compared to the 37 Military Hospital site. In addition, bats were five times more likely to test positive for the virus during the rainy season as compared to the dry season.

Eidolon bat coronavirus was most commonly detected in *Eidolon helvum* bats (33% positive), followed by Gambian Epauletted fruit bats (1% were positive). The virus was primarily detected at the 37 Military Hospital site where we sampled bats at the large urban roost. (See the special feature below for a more in-depth investigation of the dynamics of coronavirus shedding in urban *Eidolon helvum* bats in Ghana). None of the non-human primate samples tested positive for the target viruses.

These findings contribute to our knowledge base on viruses circulating among wild animals at these high-risk interfaces. For instance, our findings suggest that coronaviruses circulate among bats more commonly during the rainy season when the dams are weaning pups and there are higher numbers of susceptible individuals in the population. Detection of these viruses in wildlife provides opportunities to learn more about their ecology and risk of cross-species transmission and to identify mitigation strategies aimed at preventing human infections.

VIRUS TABLE

VIRAL FAMILY	VIRUS	SPECIES	SAMPLING LOCATION	# OF POSITIVE INDIVIDUALS TOTAL	WET SEASON	DRY SEASON
Coronavirus	Betacoronavirus 1 (OC43)	Human	Nkoranza North District Health Centers 1 & 2, 37 Military Hospital	4	2	2
	Coronavirus 229E (Human strain)	Human	Nkoranza North District	1	1	0
	PREDICT_CoV-102	Gambian Epauletted Fruit Bat	Nkoranza North District	1	0	1
	Chaerephon bat coronavirus/Kenya/KY22/2006	Angolan Free-Tailed Bat, Straw-Coloured Fruit Bat, Gambian Epauletted Fruit Bat	Nkoranza North District, 37 Military Hospital Grounds	4	3	1
	Eidolon bat coronavirus	Gambian Epauletted Fruit Bat, Straw-Coloured Fruit Bat	Nkoranza North District, 37 Military Hospital Grounds	77	52	25
	Kenya bat coronavirus/BtKY56/BtKY55	Angolan Free-Tailed Bat, Buettikofer's Epauletted Fruit Bat, Franquet's Epauletted Fruit Bat, Gambian Epauletted Fruit Bat, Straw-Coloured Fruit Bat	Nkoranza North District, 37 Military Hospital Grounds	81	51	30
Paramyxovirus	Human parainfluenzavirus 2	Human	Nkoranza North District Health Center 1	1	1	0
	Human parainfluenzavirus 3	Human	Nkoranza North District Health Center 1	1	0	1
	Mumps virus	Human	Nkoranza North District Health Center 2	1	0	1
	PREDICT_PMV-15	Angolan Free-Tailed Bat	Nkoranza North District	1	0	1
	PREDICT_PMV-56	Straw-Coloured Fruit Bat	37 Military Hospital Grounds	2	2	0
	PREDICT_PMV-168	African Giant Shrew	37 Military Hospital Grounds	3	2	1
	PREDICT_PMV-170	African Giant Shrew	37 Military Hospital Grounds	1	0	1
	PREDICT_PMV-171	Deroo's Mouse	Nkoranza North District, 37 Military Hospital Grounds	7	5	2
Influenza virus	Influenza A	Human	Nkoranza North District, Nkoranza North District Health Centers 1 & 2, 37 Military Hospital	24	19	5
	Influenza B	Human	Nkoranza North District Health Centers 1 & 2	5	0	5
Total				**214**	**138**	**76**

EPIDEMIOLOGICAL & BEHAVIORAL RISK

Our PREDICT team partnered with local communities to learn more about people's awareness and perceptions of risk of zoonotic diseases and the environmental factors and types of activities they engage in that might influence the risk of disease transmission, including human demographics, livelihood activities, animal distributions, animal contact, and food safety and sanitation practices. From November 2017 to December 2019, 653 individuals participated in the syndromic and community-based surveillance efforts (264 community members and 342 patients at the Nkoranza North District site and 47 patients at the 37 Military Hospital (see Participant characteristics table below)). Participants were enrolled across the rainy and dry seasons. Each person was sampled and asked to fill a questionnaire that gathered information on potential risk factors for zoonotic virus spillover and spread.

PARTICIPANT CHARACTERISTICS ACROSS ALL SURVEILLANCE SITES

SITES	COMMUNITY-BASED SURVEILLANCE	CLINIC-BASED SURVEILLANCE	
	Nkoranza North District (n=264)	Nkoranza North District* (n=319)	37 Military Hospital (n=47)
GENDER (FEMALE)	130 (49%)	132 (41%)	24 (51%)
GENDER (MALE)	134 (51%)	187 (59%)	24 (51%)
AGE** (YEARS)	43 (6-85)	19 (2-81)	30 (3-75)

*Nkoranza North District Health Centers 1 & 2
**median and range

CLINIC-BASED SURVEILLANCE

We conducted surveillance at local clinics in the Nkoranza North District communities (NNDHCs) and the 37 Military Hospital (37MH) to better understand viral causes of illness among our target communities. Our teams enrolled patients presenting with history of acute febrile illness (1-5 day duration for most participants); safely took samples to test for corona, paramyxo, flavi, arena, filo, and influenza viruses; and administered questionnaires to collect data on risk factors for zoonotic virus transmission. Patients reported a range of symptoms in addition to fever, including headache (77%), cough (65%), abdominal pain (29%), muscle and/or joint pain (24%), or a combination of these symptoms. Symptoms did not vary by age or gender of the patients.

The majority of patients enrolled in the project were students (NNDHCs: 35%; 37MH: 25%) followed by agricultural workers (NNDHCs: 28%; 37MH: 9%) and non-animal business workers (NNDHCs: 8%; 37MH: 45%). Among the agricultural workers, the participants were most commonly engaged in crop production (96%) and to a lesser extent animal production for their primary livelihood.

COMMUNITY-BASED SURVEILLANCE

From 2017-2018, 264 participants were enrolled in our community-based surveillance activities at the Nkoranza North District site using systematic random sampling. The majority of participants (73%) were engaged in crop production and also raised domestic fowl (chickens and ducks), sheep, and pigs, primarily for household consumption. These animals are raised in extensive semi-scavenging systems where animals free-range during the day and return to mixed animal outdoor enclosures at night. Almost all of the crop farmers (98%) reported crop raiding by animals, primarily by non-human primates, rodents, bats, and wild birds. With the exception of non-human primates, deterrents were common and included trapping, shooting, and poisoning the animals to mitigate loss of crops. Sixty-two percent of individuals reported an outbreak of disease in animals during the past year (poultry and sheep), yet only 18% indicated that sick animals were treated, quarantined, or culled. In addition, night soil (human excrement) and manure from poultry and sheep were commonly used as fertilizer (61%: 48/79), which if unprocessed, can also be a source of pathogens.

Nearly all respondents reported animals entering their homes (99%), including non-human primates (92%), domestic fowl (88%), sheep (79%), rodents and shrews (29%), and bats (5%). In addition, 74% of respondents consumed food that had been handled or damaged by animals and 70% observed animal feces and extreta (from poultry: 56%; non-human primates: 36%; rodents: 21%) in or near food sources. Over half (52%) of the community members said household food was not stored in closed containers, facilitating access by rodents and non-human primates.

Hunting was not commonly reported (12%) in these communities; however, rodent and bat hunting were observed at the site and 50% of individuals indicated that bushmeat was locally available. In addition, several individuals reported eating animals that they found ill (30%) or dead (13%). Further, over half of the respondents (54%) either did not know or did not perceive any risks of disease transmission from wounds when butchering an animal, which might explain why 19% of people reported that they do not take any preventive measures or seek treatment from a doctor when injured during animal butchering.

PREDICT conducted community outreach to increase awareness of zoonotic diseases and discuss the goals of the project; PREDICT Ghana team members held a durbar with the chiefs and members of the Nkoranza North District communities to discuss plans for the PREDICT project in Ghana and to seek their input and collaboration on the project; community members

RISK COMMUNICATION

Given the zoonotic disease risk associated with bat contact that was identified through PREDICT's surveillance activities, we conducted community outreach campaigns in the Nkoranza North District communities to increase awareness and promote risk reduction strategies. Our teams, led by trusted Health Promotion Officers from the Ghana Health Service and a local Wildlife Conservation Officer, held a risk reduction campaign using materials developed by the PREDICT project, including PREDICT's behavior change communication and risk reduction resource *Living Safely with Bats*. More than 500 community members participated in this event to learn about bats, their important contributions to ecosystem services, and strategies for reducing risk of exposure to bat-borne zoonoses, while ensuring conservation of the bats. The outreach focused most intensively on how to exclude bats from entering homes in the villages, given this type of bat contact was brought to light through PREDICT's work in the community.

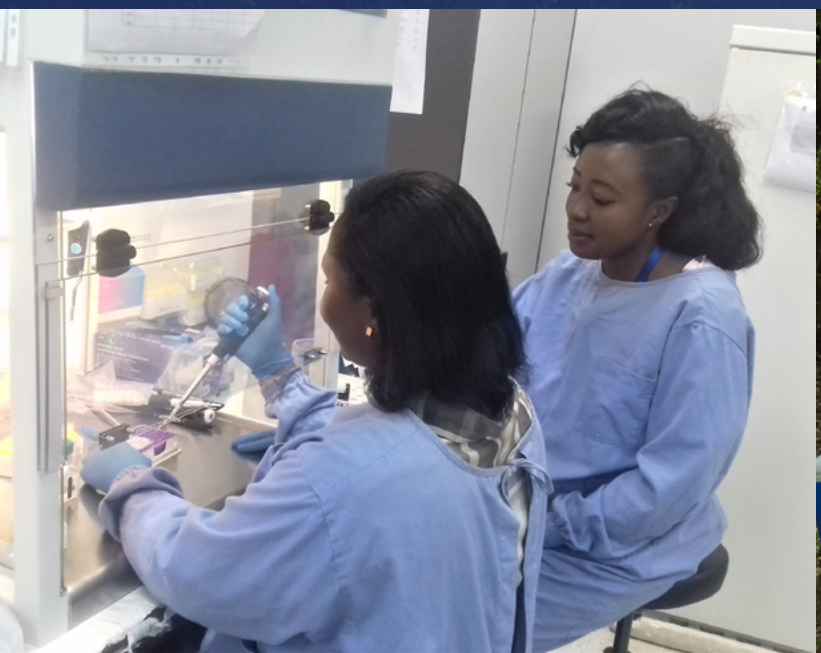
STRENGTHENING CAPACITY

PREDICT provided a range of training opportunities designed to strengthen existing capacities in disease surveillance and risk assessment for current and emerging zoonotic viral threats. PREDICT team members from government and university partner organizations across the human, environmental, and animal health sectors participated in local, regional, and international workshops as well as field-based and laboratory-based exercises to strengthen One Health networks and enhance knowledge and skills required for a One Health Workforce.

For example, joint on-the-job trainings were provided that reinforced concepts and skills in biosafety, safe capture and sampling of wildlife, specimen handling and maintenance of a cold chain, virus detection using consensus PCR, and disease outbreak response. In addition, trainings developed to strengthen risk assessment capacities were supported, including phylogenetic analyses and spatial risk assessment and modeling. PREDICT team members who have participated in these trainings are now sharing knowledge and skills with colleagues in the government and at the university through a "train-the-trainer" approach.

"PREDICT has significantly expanded the scope of disease surveillance in Ghana to include a focus on zoonotic diseases and an improved ability to detect novel zoonotic viruses that may be the cause of undiagnosed illnesses in Ghana."

– Dr. Franklin ASIEDU-BEKOE,
Head of Disease Surveillance,
Ghana Health Service



OUTBREAK PREPAREDNESS & RESPONSE

PREDICT responded to a request by the Ghana government to support the investigation of a suspected Lassa Fever case in Ghana in March, 2018. Based on consultation with Ghana Health Service regarding locations where the deceased patient was residing during the 30 day period prior to illness, the team conducted field investigations at two sites: Adenta and Ashaiman New Town.

In collaboration with the Ghana Health Service and with support from FAO, PREDICT personnel from the Wildlife Division of the Forestry Commission and Veterinary Services Directorate, conducted the field investigations, safely sampling rodents in Adenta and Ashaiman New Town. In total, 52 rodents were sampled and tested for Lassa fever. The team also administered questionnaires in the local community. The government of Ghana views this effort as a One Health success story where personnel representing the three ministries worked collaboratively to investigate the circumstances of the case, assess rodent reservoirs of the virus around the communities, and evaluate human practices that could put this community at greater risk of exposure. PREDICT also worked with the Ghana Health Service and the School of Public Health to educate the community on Lassa fever and strategies to reduce their risk.

PRACTICAL IMPLICATIONS

PREDICT's work strengthened One Health platforms in Ghana through enhancing capacities in One Health surveillance, detection of emerging viral zoonoses, and multi-sectoral collaboration during disease outbreak investigations. The project established mechanisms to sustain One Health approaches through buy-in from stakeholders on the value of multi-sectoral partnerships in disease surveillance and disease outbreak investigation, protocols for detection of emerging viruses, and sharing of animal and human disease surveillance data. This is evidenced by the uptake of PREDICT's virus detection protocols in laboratories used by the government to investigate undiagnosed causes of illness in humans and animals and the government's designation of sentinel sites for zoonotic disease surveillance in the country.

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SPECIAL FEATURE

Peak Season for Viral Shedding at Urban Fruit Bat Roosts

Our team collaborated with scientists from UC Davis and Tanzania to assess the seasonality of coronavirus (CoV) shedding by the straw-colored fruit bat (Eidolon helvum) in large urban fruit bat roosts. We non-invasively collected fecal samples from the bats monthly over an annual cycle at two bat colonies: one at the 37 Military Hospital in Accra, Ghana and one in Morogoro, Tanzania. In parallel, we collected data on the roost sizes and precipitation levels and established the reproductive periods through the year (e.g., birth pulse, weaning of pups, etc.). The results suggest an association between the reproductive cycle of the bats and CoV shedding, with a ~4 times higher proportion of positive fecal samples during the pup weaning period compared to other periods of the year.

Read more about this study at
http://bit.ly/2O2creo

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