



USAID
FROM THE AMERICAN PEOPLE

PREDICT VIETNAM

One Health in action (2009-2020)



Preventing pandemics, protecting global health

VIET NAM



The PREDICT project in Viet Nam was a collaborative effort with the Vietnamese government agencies within the environment, animal health, and public health sectors to address the threat of emerging pandemic diseases facilitated by the interaction of wildlife, domestic animals, and humans (the human-animal interface). The PREDICT team focused on investigating and understanding the potential transmission of infectious diseases between wildlife, livestock, and humans at key human/wildlife/domestic animal interfaces along the animal value chains and animal production systems, including the wildlife trade, live animal markets, and bat guano collection sites to prevent pandemic disease emergence and negative impacts on human health. The PREDICT team also conducted behavioral surveillance to gather relevant information about risky human behavior and practices to provide a better understanding of the drivers for zoonotic spillover and host-pathogen dynamics. While core PREDICT objectives centered on protecting human health, wildlife conservation benefits included improved diagnostic laboratory capacity for wildlife disease surveillance and greater governmental awareness and investment in wildlife population management.

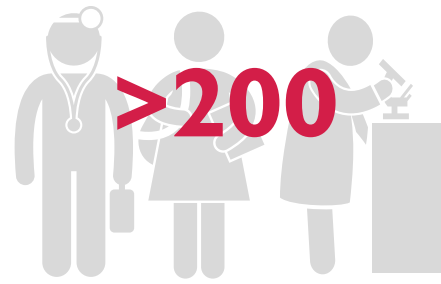
The PREDICT project used a One Health approach

to understand the dynamics of zoonotic virus evolution, spillover, amplification, and spread to inform prevention and control. Samples were safely collected at the high-risk interfaces from wild rodents, bats, carnivores, and non-human primates, in addition to human populations. Through this collaborative effort with Vietnamese research, academic, and government institutions, the PREDICT team collected nearly 7,000 samples from wildlife and completed over 16,000 assays in Vietnamese and international laboratories to identify known and novel viruses.

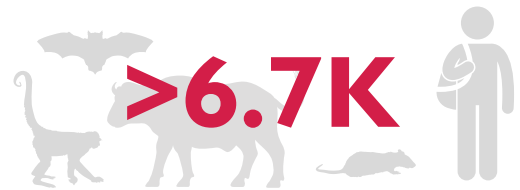
The PREDICT project's zoonotic disease surveillance was strategically designed to train, equip, and enable surveillance personnel from the animal and human health sectors to collect data and build the evidence base for both priority zoonoses and emerging and re-emerging diseases such as viral hemorrhagic fevers in vulnerable and high-risk areas. Shared animal and human surveillance data and findings helped catalyze formal information sharing between animal and human surveillance systems. In addition, our surveillance engaged local communities in high-risk areas for disease transmission and emergence and fostered improved recognition of zoonotic diseases and awareness of transmission pathways and prevention and control options.

LOCAL PARTNERS

- Department of Animal Health (DAH), Ministry of Agriculture and Rural Development (MARD)
- Dong Nai Province Forest Protection Department
- Endangered Primate Rescue Center (EPRC)
- Food and Agriculture Organization (FAO)
- National Institute of Hygiene and Epidemiology (NIHE), Ministry of Health (MoH)
- Regional Animal Health Office No. 6 & 7 (RAHO6&7)
- Save Vietnam's Wildlife (SVW)
- University of California, Davis (UCD)
- USAID
- Viet Nam National University of Agriculture (VNUA)
- Viet Nam One Health University Network (VOHUN)
- Wildlife Conservation Society
- World Health Organization (WHO)



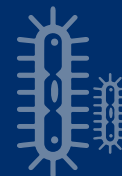
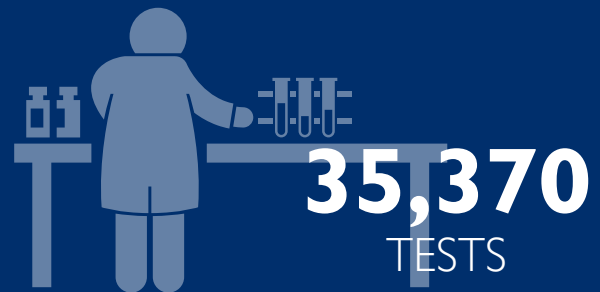
DEVELOPED the One Health Workforce by training more than 200 people in Viet Nam.



OPERATIONALIZED One Health surveillance and sampled over 6.7K animals and people, helping minimize the spillover of zoonotic disease threats from animals into human populations.

LABORATORY STRENGTHENING

- Viet Nam National University of Agriculture
- Regional Animal Health Office No. 6
- National Institute of Hygiene & Epidemiology



DETECTED 44 unique viruses in both animals and human populations.



NGUYEN THI THANH NGA

Health Team Manager, *Wildlife Conservation Society*

“I started my career as a member of the PREDICT Project. Being a part of the team helps me deepen my expertise, improves my skills, and gives me a golden chance to explore the areas that I’m interested in—wildlife, wildlife health and zoonotic diseases. PREDICT has helped me enhance my veterinary skills and its findings bring value to animal health, especially wildlife health, in Viet Nam.”



VU TRONG DUOC

Human Health Surveillance & Laboratory Lead, *National Institute of Hygiene & Epidemiology*

“The PREDICT project has built the capacity for government staff directly involved in the project to improve their existing professional skills and update other knowledge from the project. With the National Institute of Hygiene and Epidemiology, following the completion of the project, the results provided significant contributions to develop a pathogen detection and monitoring plan, and help us to confidently continue other studies based on the experience gained from the PREDICT project.”

ACHIEVEMENTS

- We established a working relationship with public health sectors and collaborated with animal health sectors to implement a One Health project.
- More than 140 project partners were engaged in building capacity for novel virus detection and concurrent surveillance for zoonotic diseases in human and animal populations in Viet Nam through PREDICT. Specifically, the skills training in wildlife disease surveillance has built core capacity within Viet Nam’s human and animal health sector to investigate and characterize the disease risks associated with the unregulated and illegal trade in wildlife.
- PREDICT Viet Nam strengthened diagnostic capacity in national animal health and public health laboratories for the early detection of known and novel viruses of pandemic potential to predict and prevent disease emergence.
- PREDICT Viet Nam’s human syndromic surveillance was conducted in 3 sites across Viet Nam with 1,200 people enrolled in the surveillance.
- PREDICT Viet Nam worked in close collaboration with the Secretariat Office of the Viet Nam One Health Partnership, General Department of Preventive Medicine of Ministry of Health, Department of Animal Health of Ministry of Agriculture and Rural Development, Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization (WHO) to improve coordination of surveillance efforts across the wildlife, livestock, and human health sectors for influenza and other viruses with pandemic potential in populations in Viet Nam. PREDICT’s One Health approach to zoonotic disease surveillance was linked with national surveillance systems for Severe Acute Respiratory Illness (SARI) in people, and influenza surveillance in livestock, so that data can be analyzed jointly to inform disease risk assessments and support disease prevention strategies designed to disrupt the amplification and spread of important respiratory pathogens. This coordination of surveillance activities in Viet Nam is also known as Longitudinal Influenza Surveillance Network (LISN) which is conducted in livestock, wildlife and humans at their interface or points of contact to identify influenza A virus and other potential pandemic threats.



ONE HEALTH SURVEILLANCE

Prioritizing & operationalizing risk reduction

Viet Nam has been a leader in advancing One Health in practice since 2006 through development of coordinated approaches to tackle Highly Pathogenic Avian Influenza and in its current role as a co-lead for the Global Health Security Agenda (GHS) Zoonotic Diseases Action Package. In 2016 the country established an updated 5-year One Health Strategic Plan for zoonotic diseases, which integrates One Health across more than 20 national sectoral and topical plans to strengthen capacity, enhance preparedness, and reduce impact of priority zoonoses and antimicrobial resistance. The plan's six main focus areas include a dedicated item on prevention of infectious disease emergence (Focus Area 3: One Health approaches for managing zoonotic agents with pandemic potential that are yet to emerge), with specific outcome indicators on: i) Identification of risk factors or interfaces associated with spill-over, amplification and/or spread, and ii) Implementation of risk reduction strategies based on identified risk factors. The plan also recognizes the need for environmental health research on disease drivers (for example, on land use practices) and greater engagement overall of the environment sector through guidelines, policies, and resource allocation to support One Health capacity building.

WHAT ONE HEALTH ADDED

To date, the emphasis for novel disease outbreaks has been on mobilizing effective and rapid response to avoid international disease spread. Viet Nam's application of One Health promotes a preventive stance that moves upstream to target pathogen spillover at the source to avoid or reduce human and animal disease and their associated health and economic consequences. The plan has been made operational through initial activities at key interfaces where wildlife-human exposure is common and presents potential zoonotic disease transmission

pathways (e.g., live animal markets, bat guano collection sites, and wildlife restaurants). PREDICT has been a key partner in strengthening capacity for sample collection and screening for novel pathogens, addressing key challenges identified in the plan, including workforce development for risk monitoring and mitigation at high-risk animal-human interfaces (wildlife farms, bat guano harvest sites, and rodent trade routes) through on-the-job training for Dong Nai Province Forest Protection Department, the Regional Animal Health Office No. 6 & 7, and National Institute of Hygiene and Epidemiology staff who participated in PREDICT surveillance planning, sample collection, and diagnostic activities. With PREDICT's support, all partner laboratories, including national public health and animal health laboratories in Viet Nam, are trained in the full range of activities required for safely detecting zoonotic viruses, such as biosafety and biosecurity, cold chain, safe sample storage, data management, safe sample transport and shipping, and molecular viral detection techniques.

The country has also recognized the need for multisectoral information sharing to promote biodiversity and health mainstreaming across a range of stakeholders. For example, PREDICT shared results and lessons on human health risks associated with the illegal wildlife trade at a United Nations Office on Drugs and Crime (UNODC) training on the Penal Code in July 2018, helping to strengthen awareness about a potential driver of disease emergence in addition to biodiversity loss. Viet Nam's national commitment to reducing the threat of novel pathogens is a model for all countries to get ahead of disease emergence events, which is adaptable to high-risk species and exposure interfaces relevant to each country or community.

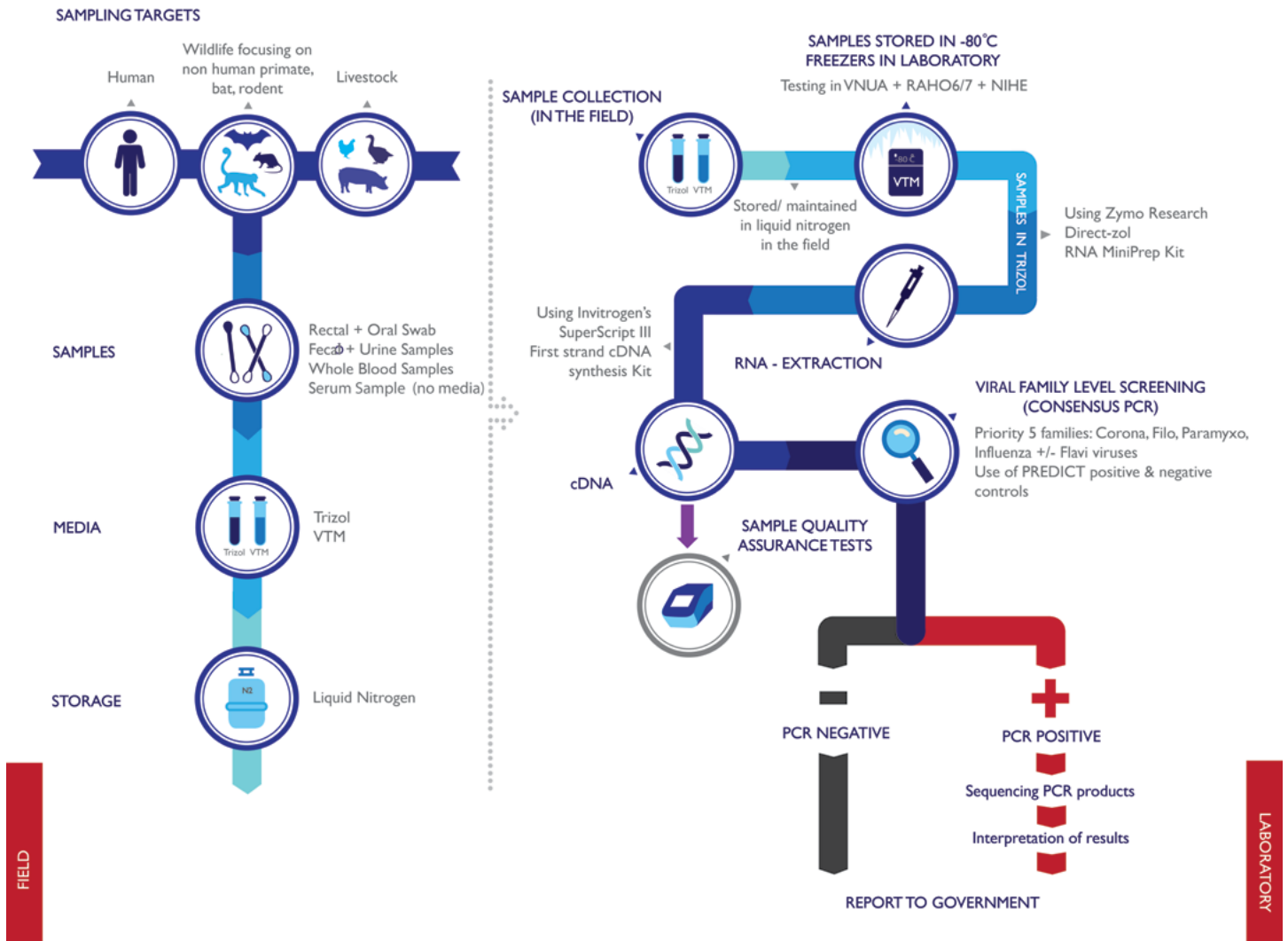
Read more at bit.ly/2BKgrxg

VIRUS DETECTION

PREDICT is the first project to use consensus polymerase chain reaction (cPCR) as the primary method for detection of both known and novel viruses in a wide range of samples and host species on a global scale (Goldstein et al. 2013; Anthony et al. 2013). The advantages of this approach include:

- An inexpensive testing method (cPCR) run on basic equipment, such as thermal cyclers for conventional PCR already available in animal and human health laboratories in Viet Nam.
- The “universal” amplification of viruses within a given viral family or genus.

- Synthetic ‘universal controls’ that provide standardized control material without any danger of pathogen transmission.
- Increased safety to laboratory workers as any microbes in the samples are killed during the PREDICT nucleic acid extraction steps so laboratory workers are not exposed to dangerous pathogens.
- Ability to extend the PREDICT diagnostic strategy beyond the detection of viruses in wildlife to the diagnosis of mystery illnesses in medical hospitals or in solving an unknown disease outbreak in livestock or domestic animals.



VIRUS TABLE

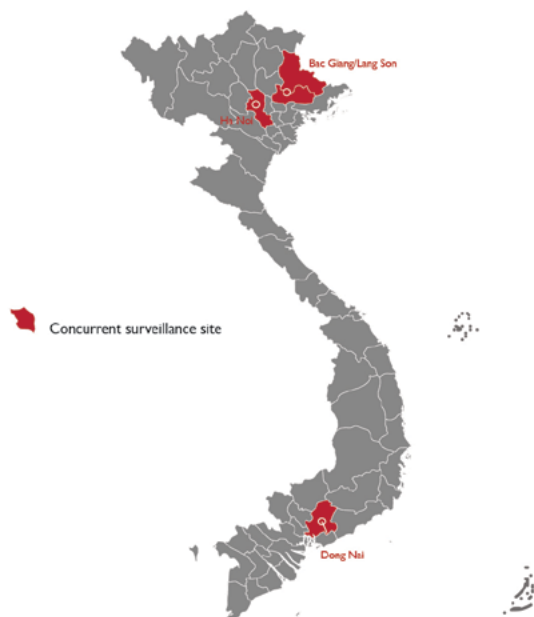
VIRAL FAMILY	VIRUS	SPECIES	SAMPLING LOCATION	# OF POSITIVE INDIVIDUALS			
				TOTAL	WET SEASON	DRY SEASON	
Coronavirus	PREDICT_CoV-35	Unidentified Vesper Bat	Dong Thap	5	5	0	
	PREDICT_CoV-47	Unidentified Bat, Wrinkle-Lipped Free-Tailed Bat	Bac Giang	12	12	0	
	PREDICT_CoV-82	Wrinkle-Lipped Free-Tailed Bat	Bac Giang	2	2	0	
	PREDICT_CoV-99	Unidentified Bat	Bac Giang	1	1	0	
	Bat coronavirus 512/2005	Lesser Asian House Bat, Unidentified Vesper Bat	Dong Thap	38	38	0	
	Longquan Aa mouse coronavirus	Hoary Bamboo Rat, Norway Rat, Oriental House Rat, Ricefield Rat	Dong Nai, Dong Thap, Thach That	11	11	0	
	Murine coronavirus	Black Giant Squirrel, Black Rat, Greater Bandicoot Rat, Hoary Bamboo Rat, Lesser Ricefield Rat, Malayan Porcupine, Norway Rat, Polynesian Rat, Ricefield Rat, Unidentified Rat	Dong Nai, Dong Thap, Thach That	92	90	2	
	Rodent coronavirus	Lesser Ricefield Rat, Norway Rat, Polynesian Rat, Ricefield Rat, Unidentified Rat	Dong Thap, Thach That	23	12	11	
	Alphacoronavirus 1 (Transmissible gastroenteritis virus)	Domestic Pig	Dong Nai	19	0	19	
	Betacoronavirus 1 (Porcine hemagglutinating encephalomyelitis virus)	Domestic Pig	Dong Nai, Dong Thap, Quang Ninh	80	38	42	
	Infectious bronchitis virus (IBV)	Domestic Chicken	Dak Nong	2	0	2	
	Paramyxovirus	Human parainfluenzavirus 3	Human	Dong Nai	1	1	0
		Measles virus	Human	Bien Hoa City Clinic (Dong Nai)	2	1	1
Mumps virus		Human	Bien Hoa City Clinic (Dong Nai)	1	1	0	
PREDICT_PMV-63		Unidentified Vesper Bat	Dong Thap	1	1	0	
Beilong virus		Norway Rat	Thach That	2	2	0	
Newcastle disease virus		Domestic Chicken	Dak Nong	1	0	1	
Porcine parainfluenzavirus 1		Domestic Pig	Dong Nai, Dong Thap, Quang Ninh, Swine Farms DTH01 & DTH05	7	3	4	
Influenza virus	Influenza A	Human, Domestic Pig	Bien Hoa City Clinic (Dong Nai), Dong Nai, Thach That Clinic, Quang Ninh, Swine Farms DTH02 & DTH03 & DTH06	38	26	12	
	Influenza B	Human	Dong Nai, Thach That Clinic	2	1	1	
Flavivirus	Dengue virus serotype 1	Human	Bien Hoa City Clinic (Dong Nai), Thach That Clinic	6	5	1	
	Dengue virus serotype 2	Human	Bien Hoa City Clinic (Dong Nai), Thach That, Thach That Clinic	17	16	1	
Total				363	266	97	

CONCURRENT SURVEILLANCE & THE WILDLIFE-FARM INTERFACE

The PREDICT project's One Health team worked with national, provincial, and district-level veterinary and medical officers to strengthen multi-sectoral information sharing (a challenge identified in the Joint External Evaluations, a process to assess Viet Nam's capacity to prevent, detect, and rapidly respond to public health risks) and to extend Viet Nam's surveillance system to high-risk areas for zoonotic disease transmission including sites with high rates of wildlife trade and intensive farming of wildlife. PREDICT's concurrent surveillance at high-risk sites contributes to Viet Nam's syndromic surveillance of febrile patients at district and provincial hospitals, screening of people in the community with occupational risk to zoonotic diseases through wildlife trade and wildlife farming, wildlife disease surveillance, and surveillance for pathogens of pandemic potential in livestock in collaboration with FAO and the Department of Animal Health (DAH) of the Ministry of Agricultural and Rural Development (MARD).

WILDLIFE-FARM INTERFACE IN DONG NAI PROVINCE

A high number of wildlife farms are located in Dong Nai Province. The wildlife farms are stocked with wild animals sourced from captive and wild populations. Government agencies, including the Provincial Forest Protection Department and Sub-Department of Animal Health, supported PREDICT's surveillance activities in the wildlife farms and adjacent domestic animal farms; and the Provincial Preventive Medicine Center and Dong Nai Department of Health supported PREDICT's human surveillance in the community and hospitals. The PREDICT team prioritized wildlife farms, nearby livestock, hospital patients, and community members involved in wildlife farming for zoonotic disease surveillance activities due to the close and frequent human-wildlife contact. Targeted sites included districts that have farms that supply three main species (rodents, non-human primates, and civets).



SPECIES COMMON NAME	VIRUS	# SPECIMENS
Human (Hospital)	Dengue virus serotype 1	5
	Dengue virus serotype 2	15
	Influenza A	11
	Measles virus	2
	Mumps virus	1
Black giant squirrel	Murine coronavirus	1
Domestic pig	Alphacoronavirus 1 (Transmissible gastroenteritis virus)	19
	Betacoronavirus 1 (Porcine hemagglutinating encephalomyelitis virus)	35
	Porcine Parainfluenzavirus 1	2
Hoary bamboo rat	Longquan Aa mouse coronavirus	1
	Murine coronavirus	21
Human (Community)	Influenza A	1
	Influenza B	1
	Human Parainfluenzavirus 3	1
Malayan porcupine	Murine coronavirus	6

WILDLIFE MARKET INTERFACE IN HA NOI METROPOLITAN AREA

Ha Noi, with a population of 7.7 million people, is located on an important wildlife trafficking route in Southeast Asia. It is an urban site for the field rat market trade (Animal Value Chain), with numerous people engaged in the capture, sale, and slaughter of the rats. Domestic animals also move through the same markets and restaurants. The PREDICT project

conducted surveillance on trafficked animals as well as rodents, which have been listed as a key high-risk taxa for zoonotic pathogens. For these reasons, PREDICT selected Ha Noi as a priority for human, domestic animal, and wildlife surveillance activities. The targeted site was Thach That District, which is the main location of rat consumption and home to many people who are exposed to wildlife on a regular basis during their daily activities.

SPECIES COMMON NAME	VIRUS	# SPECIMENS
Human (Hospital)	Dengue virus serotype 1	1
	Dengue virus serotype 2	1
	Influenza A	7
	Influenza B	1
Human (Community)	Dengue virus serotype 2	1
Norway rat	Beilong virus	2
	Longquan Aa mouse coronavirus	1
	Murine coronavirus	11
	Rodent coronavirus	20
Oriental house rat	Longquan Aa mouse coronavirus	3
Ricefield rat	Rodent coronavirus	2

BAT GUANO HARVEST INTERFACE IN BAC GIANG & DONG THAP PROVINCES

Bac Giang Province has a large cave that provides a roosting habitat for migratory bats. The guano produced by the bats is collected by individuals to use as plant fertilizer. Inside the cave, the bat guano harvesters and cave owners are exposed to overhead droppings and regularly walk through piles of feces with bare feet. The PREDICT team

investigated zoonotic disease spillover risk at this natural site and at constructed bat guano farms where the bat guano is collected and harvested by hand (Dong Thap Province). The team used observational research and informal discussions to characterize the guano collection process and identify the roles of individuals within the value chain. Subsequently, we confirmed guano collection as well as adjacent domestic animal holdings as a priority for human, bat, and domestic animal surveillance activities.

SPECIES COMMON NAME	VIRUS	# SPECIMENS
Unidentified bat	PREDICT_CoV-47	8
	PREDICT_CoV-99	1
Wrinkle-lipped free-tailed bat	PREDICT_CoV-47	5
	PREDICT_CoV-82	2

LONGITUDINAL INFLUENZA SURVEILLANCE NETWORK (LISN)

A cohesive understanding of the burden of various priority pathogens, animal/livestock market chains, and the evolution of influenza viruses in Viet Nam requires coordination of human-animal interface surveillance outputs. Therefore, FAO, WHO, and the PREDICT team worked jointly in Viet Nam to link some parts of existing influenza surveillance in livestock, wildlife, and humans with the goal to support the Ministry of Health (MOH) and Ministry of Agriculture and Rural Development (MARD) to enhance detection and characterization for influenza and other viruses with pandemic potential in Viet Nam. This linking of existing surveillance activities

is also known as Longitudinal Influenza Surveillance Network (LISN). LISN also enhances Viet Nam's application of One Health principles to strengthen cross-sectoral collaboration and coordination for both disease outbreak events and routine disease surveillance activities.

After mapping existing surveillance activities and known value chains, the following provinces were selected as sites for implementation:

- Dong Thap Province: South-West Viet Nam: duck grazing activity, movement of spent ducks, rodent trade, and bat guano harvest practices.
- Quang Ninh Province: North-East Viet Nam: movement of chickens, wildlife trade.

SPECIES COMMON NAME	VIRUS	# SPECIMENS
Domestic pig	Betacoronavirus 1 (Porcine hemagglutinating encephalomyelitis virus)	38
	Porcine Parainfluenzavirus 1	1
Greater bandicoot rat	Murine coronavirus	1
House rat	Murine coronavirus	2
Lesser Asian house bat	Bat coronavirus 512/2005	4
Lesser Ricefield rat	Murine coronavirus	7
	Rodent coronavirus	1
	Murine coronavirus	3
Ricefield rat	Rodent coronavirus	1
	Longquan Aa mouse coronavirus	12
	Murine coronavirus	59
	Rodent coronavirus	6
Unidentified <i>Myotis</i> bat	PREDICT_CoV-35	5
	PREDICT_PMV-63	1
	Bat coronavirus 512/2005	43
Unidentified <i>Rattus</i> rat	Murine coronavirus	2
	Rodent coronavirus	2

OPPORTUNISTIC ACTIVITIES ALONG THE WILDLIFE TRADE CHAIN

Illegal wildlife trade or wildlife trafficking (Animal Value Chain) was an important interface for the PREDICT project. PREDICT established relationships

with partners with knowledge of wildlife confiscation events that may involve a variety of wild animal taxa at the destination, source, or transit sites throughout the country. Therefore, as opportunities were available and feasible, PREDICT teams conducted surveillance activities on confiscated wildlife.

SPECIES COMMON NAME	VIRUS	# SPECIMENS
Red junglefowl	Infectious Bronchitis Virus (IBV)	4
	Newcastle Disease Virus	2

BEHAVIORAL RISK SURVEILLANCE

A primary goal of the PREDICT project was to strengthen global capacity for the detection and discovery of viruses with pandemic potential, specifically those that can move between animals and people (zoonotic viruses). The PREDICT team worked to improve the characterization of associated biological, behavioral, and ecological risks to better understand which geographic locations, 'epidemiological zones', animal-animal and/or animal-human interfaces, and environmental factors are most associated with the evolution, spillover, amplification, and spread of zoonotic viruses with pandemic potential. Ethnographic interviews were

used to identify risk factors associated with zoonotic disease transmission risk.

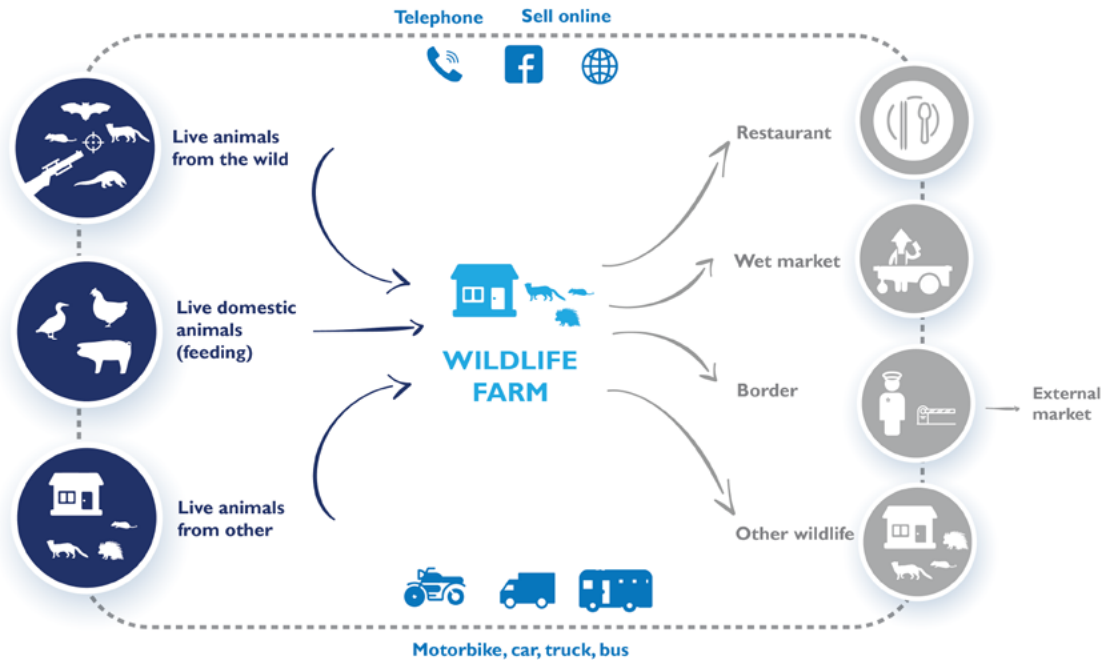
Analysis of PREDICT biological and behavioral surveillance in human populations at key animal-human interfaces potentially associated with the spillover, amplification, and spread of zoonotic viruses is underway. Biological samples were safely collected from humans enrolled in the project for viral testing, and quantitative and qualitative research methods are used to identify risk factors for viral transmission and obtain descriptive accounts of human behaviors and perceptions to support the development of effective public health interventions. Enrollment of humans was part of PREDICT's triangulated surveillance for viruses of pandemic potential in wildlife, domestic animals, and humans at key concurrent surveillance sites.

I've only heard about zoonotic diseases from poultry. Such as chicken, pigeon and also other livestock. I brought civets here and then vaccinated them. In my opinion maybe there are zoonotic diseases that pass from civets to humans but my animals are vaccinated so I can have peace."

—Civet farm owner

My father told me when I was a child, whenever I was bitten by snake and rat or when I got cut, just suck the blood. He taught me that."

—Rat hunter



Read more about this study here: www.biorxiv.org/content/10.1101/2020.06.05.098590v3

In Viet Nam as well as Cambodia and Laos, an important rodent-human interface is the live field rat trade. Based on numbers from the early 2000s the Vietnamese live field rat market was valued at US\$2 million and it was estimated that 3,300-3,600 tonnes of live rats were consumed annually (Khiem 2003). This unique zoonotic disease interface involves the capture of wild caught rice field rats and their subsequent trade along a value chain in the Mekong Delta region of these countries. One of the surveillance activities of the

PREDICT project focused on this live field rat trade, where we targeted large markets (>20 vendors), trade sites (involved in private sale and processing of live rodents for consumption), and restaurants. Five field rat species were found in the trade (*Rattus argentiventer*, *R. tanezumii*, *R. norvegicus*, *R. exulans*, and *Bandicota indica*). Characterization of which viruses are present and viral family level detection rates along the value chain can help mitigate zoonotic disease risks by informing policy and intervention options.

REFERENCES:

1. Berto A, Anh PH, Carrique-Mas JJ, Simmonds P, Van Cuong N, Tue NT, et al. Detection of potentially novel paramyxovirus and coronavirus viral RNA in bats and rats in the Mekong Delta region of southern Viet Nam. *Zoonoses Public Health*. 2018;65: 30–42. doi:10.1111/zph.12362
2. Khiem NT, Cuong LQ, Chien H Van. Market study of meat from field rats in the Mekong Delta. *ACIAR Mono. Rats, Mice and People: Rodent Biology and Management*. ACIAR Mono. 2003. pp. 543–47.
3. Wang W, Lin XD, Guo WP, Zhou RH, Wang MR, Wang CQ, et al. Discovery, diversity and evolution of novel coronaviruses sampled from rodents in China. *Virology*. 2015;474: 19–27. doi:10.1016/j.virol.2014.10.017
4. Nguyen Quynh Huong, Nguyen Thi Thanh Nga, Nguyen Van Long, Bach Duc Luu, Alice Latinne, Mathieu Pruvot, Nguyen Thanh Phuong, Le Tin Vinh Quang, Vo Van Hung, Nguyen Thi Lan, Nguyen Thi Hoa, Phan Quang Minh, Nguyen Thi Diep, Nguyen Tung, Van Dang Ky, Scott I. Robertson, Hoang Bich Thuy, Nguyen Van Long, Martin Gilbert, Leanne Wicker, Jonna A. K. Mazet, Christine Kreuder Johnson, Tracey Goldstein, Alex Tremeau-Bravard, Victoria Ontiveros, Damien O. Joly, Chris Walzer, Amanda E. Fine, Sarah H. Olson. Coronavirus testing indicates transmission risk increases along wildlife supply chains for human consumption in Viet Nam, 2013-2014. <https://www.biorxiv.org/content/10.1101/2020.06.05.098590v3>



USAID
FROM THE AMERICAN PEOPLE



EcoHealth
Alliance



METABIOTA™



Smithsonian
Institution