excerpts from

*Reducing Pandemic Risk, Promoting Global Health*

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Indonesia, a country of over 18,000 islands in equatorial Southeast Asia, has a wide range of habitats with abundant biodiversity, including endemic species of non human primates and rodents. Indonesia is considered a ‘megadiverse’ country and is home to numerous species of mammals. Bats alone account for 32% of the known mammalian diversity in the country (IUCN Red List 2014). The country’s biodiversity is at risk due to one of the most rapid rates of tropical deforestation globally, driven by increasing demands for food, forest products, and energy. These rapid ecological changes (e.g. clearing of peat swamp and tropical rain forests for oil palm plantations) are bringing humans into close contact with wildlife species that were previously rarely seen.

Indonesia has established large national parks with wildlife habitat to preserve its species diversity, and the country has an important ecotourism industry. In some parts of Indonesia, wildlife is an important source of protein, and people hunt and sell wild animals in markets and restaurants and also keep wild animals as pets. The wildlife trade, including human consumption of bats and rodents, is particularly widespread in areas of Northern Sulawesi. These human-wildlife interactions, many of which are growing through globalization, present opportunities for pathogen spillover from animals into people.

As an archipelago, Indonesia’s seas and oceans, in theory, may have historically limited spread of species of wild animals and the pathogens they may carry. However, globalization and resulting changes in human activities, including wildlife trade, are increasing movement across and beyond the country and therefore heightening the risk of cross-species transmission and the spread of pathogens. In addition, the potential for diseases to “spill-back” into animals from humans also enables greater potential pathogen spread and poses concerns for biodiversity conservation.

FOR A SUMMARY OF THIS SECTION GO TO WWW.INDONESIA.PREDICT.GLOBAL
Given the changing anthropogenic activities and the resulting increased contact between humans and wildlife in Indonesia, development of early warning systems, including expanded systematic surveillance and diagnostic capacity for potential zoonotic disease threats to people, was urgently needed. PREDICT-Indonesia was launched in the third year of the project with the goal of building an early warning platform to reduce the threat of zoonotic disease. Through a network of partnerships with scientific and government institutions, PREDICT worked to strengthen Indonesia’s capacity to conduct disease surveillance, characterize zoonotic disease risks, and respond to zoonotic disease outbreaks.

**PARTNERS**

PREDICT-Indonesia managing institutions EcoHealth Alliance, Metabiota, and the Smithsonian Institution provided advisory support and regional coordination of activities in-country. Core PREDICT activities (program coordination, surveillance, animal testing, liaising with partners, and sharing of PREDICT protocols) were implemented by the Primate Research Center at Bogor Agricultural University. A close collaboration with the Eijkman Institute for Molecular Biology with support from the US Centers for Disease Control and Prevention, allowed for testing of archived human samples to complement animal testing.

A wide range of local partners supported activities and helped enable PREDICT and One Health achievements in the country. They were instrumental in advancing training opportunities, providing knowledge and personnel for surveillance efforts and strengthening national efforts to coordinate zoonotic disease detection and response.

Important partners included:

- USAID
- Ministry of Health
- Ministry of Agriculture
- Ministry of Forestry
- Coordinating Ministry of People’s Welfare
- Indonesian Institute of Science (LIPI)
- KomNas Zoonosis Control
- Primate Research Center at Bogor Agricultural University
- Eijkman Institute for Molecular Biology
- Universitas Sam Ratulangi, Manado Sulawesi Utara
- Padjadjaran University, Bandung, Java

The PREDICT Indonesia team would like to acknowledge and express sincere appreciation for the support of Taman Safari/Bogor Botanical Gardens in the preparation and hosting of the PREDICT-Indonesia launch and training in 2012.
MAJOR ACHIEVEMENTS

- Assisted with development of the Emerging Virology Laboratory at Eijkman Institute (EVRUE) through improvements in infrastructure and personnel training (see Success Story for more information).

- Endorsed and contributed to an animal pathogen surveillance system for reporting to the national authority responsible for animal disease management. This system provides a coordinated mechanism for reporting animal diseases and improved flow of surveillance information within the country and the capacity to meet international reporting obligations to organizations such as the OIE and WHO.

- Assisted in the establishment of a National Committee for Wildlife Health, led by the Ministry of Forestry and Ministry of Agriculture. The Director General of Forest Protection and Nature Conservation decreed representation by PREDICT Indonesia on the committee.

- Collected samples from 421 animals among the three priority taxa (i.e. bats, rodents, and nonhuman primates) and obtained a suite of archived human and wildlife samples for diagnostic testing.

- Optimized 21 viral family testing protocols at the Primate Research Center, Bogor Agricultural University and Eijkman Institute laboratories for screening clinical specimens from wildlife and humans.

- In collaboration with FAO, PREDICT led a week-long laboratory training session for staff of Ministry of Agriculture at the Primate Research Center at Bogor Agricultural University. Trainees received hands-on training on using PREDICT diagnostic laboratory protocols to analyze poultry and other livestock samples for influenza viruses, paramyxoviruses, coronaviruses, and herpesviruses.

- Participated in development of a reporting system for human pathogen surveillance. Reports of activities and results are sent to the Director of the National Institute of Health Research and Development (NIHRD), the Center for Biomedical and Health Technology (at the NIHRD), the Eijkman Institute, and the National Commission of Zoonoses Control.

- In collaboration with Universitas Sam Ratulangi at Manado Sulawesi Utara, PREDICT conducted pathogen surveillance along the supply chain for the bat trade in Sulawesi and started to elucidate the bat bushmeat market chain through interactions with bat hunters and sellers. Together with the Emerging Pandemic Threats (EPT) PREVENT project, PREDICT also explored market dynamics in the country to better understand the zoonotic disease risks associated with market activities.
SUCCESS STORY

PREDICT assisted with development of the Emerging Virology Laboratory at Eijkman Institute (EVRUE) through improvements in infrastructure and personnel training. The laboratory was equipped with capabilities to test human samples for a broad range of viral families of emerging pandemic concern. The EVRUE team was increased to seven staff, all trained in advanced diagnostic methods relating to detection and characterization for emerging viruses.

This training provided EVRUE with the capacity to disseminate knowledge and techniques for enhanced emerging virus surveillance and diagnostics throughout Indonesia. PREDICT also contributed to upgrading capabilities at the Biotechnology Laboratory in the Bogor Agricultural Institute’s Primate Research Center. Together with the center’s Microbiology Laboratory, the Biotechnology Laboratory provides the testing for detection and characterization of a wide range of non-human primate viral pathogens. With support from PREDICT-Indonesia, the laboratory also increased its capacity to detect novel pathogens from wildlife.

CAPACITY BUILDING

Developing Infrastructure

To improve laboratory capacity in Indonesia, PREDICT provided the EVRUE and IPB laboratories with equipment and supplies for detection, discovery, and characterization of pathogens with zoonotic potential in humans and wildlife.

PREDICT-Sponsored Training

PREDICT provided training to over fifty individuals representing government ministries, universities, and other scientific research institutions. The training included the following: analytical approaches that would be utilized in the PREDICT project, zoonotic pathogens of bats and rodents, human and animal safety during capture, bat and rodent sampling, sample collection and cold-chain, and laboratory safety and PPE.

The training was conducted through a number of different sessions, including a workshop where 20 attendees received training on One Health approaches, sampling protocols, and hands-on training in biosafety and animal capture and sampling. The Emerging Virus Research Unit at Eijkman also actively held trainings for student, researcher, and laboratory staff from other laboratories in Indonesia. In collaboration with FAO, PREDICT led a week-long laboratory training for staff of Ministry of Agriculture at the Primate Research Center at Bogor Agricultural University. As part of the hands-on training, staff analyzed poultry and other livestock samples for influenza viruses, paramyxovirus, coronavirus, and herpesvirus using PREDICT diagnostic laboratory protocols.
Partner-Organized Trainings
PREDICT staff also benefitted from trainings hosted by local and international partners. For example, EVRUE staff attended training sessions on laboratory maintenance and virology methodology provided by the WHO Reference Laboratory, manuscript writing provided by EPT RESPOND project, and arbovirus surveillance and diagnostics at the CDC.

Sharing Technical Expertise
PREDICT-Indonesia delivered presentations on surveillance, pathogen discovery, and biosecurity methods and best practices at a wide range of government meetings and scientific conferences.

SURVEILLANCE
PREDICT conducted surveillance at a range of sites across the country (Figure 1). These sites were characterized by diverse human-animal interfaces and species, including bats, rodents, and nonhuman primates. PREDICT also implemented viral pathogen screening of human samples from persons who had close contact with wildlife in several regions in the country.

Figure 1. Sites where PREDICT conducted virus surveillance at high-risk disease transmission interfaces between wildlife and humans.
Sampling

During the three years that the PREDICT project was active in Indonesia, specimens were collected from 250 bats, 27 rodents, and 144 nonhuman primates (Figure 2). PREDICT conducted sampling at wildlife markets and at sites in diverse habitats throughout Indonesia, including urban areas and parks, lowland forests, montane rainforests, and coastal mangrove forests. In addition, bats and rodents from Tinjil Island, a semi-human modified site with a large introduced colony of long-tailed macaques (*Macaca fascicularis*), were also sampled in order to better understand cross-species transmission among the three target taxonomic groups.

Sampling was conducted at important high-risk disease transmission interfaces between animals and people, including large wildlife markets (i.e. > 20 vendors) with live and dead animals; ecotourism settings where there was contact between tourists and wildlife (mostly nonhuman primates); peri-domestic settings (i.e. in and around human dwellings/urban settings or villages); free-ranging wildlife in contact with researchers; and wildlife sanctuaries (Table 1). Wildlife wet markets and ecotourism sites were the focus of surveillance activities because of the high likelihood of close human-wildlife contact and potential for disease spillover at these interfaces.

![Sampling](image)

**Figure 2. Number of animals sampled by taxa.**

<table>
<thead>
<tr>
<th>Interface</th>
<th>Nonhuman Primates</th>
<th>Rodents and Shrews</th>
<th>Bats</th>
<th>Other Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecotourism and recreational activities</td>
<td>140</td>
<td>16</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>In or near human dwellings</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Markets</td>
<td>0</td>
<td>0</td>
<td>158</td>
<td>0</td>
</tr>
<tr>
<td>Wildlife being studied</td>
<td>0</td>
<td>11</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Zoos and sanctuaries</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>27</td>
<td>250</td>
<td>0</td>
</tr>
</tbody>
</table>
PREDICT-Indonesia’s surveillance strategy included sampling designed to assess pathogen diversity at different stages of the wildlife trade in order to better understand where and when animals in the market chain are infected with or begin shedding viral pathogens. For example, fruit bats sold at a market in Gorontalo, Northern Sulawesi were traced back to a population of wild fruit bats at sites in a mangrove forest in Boalemo district. Sampling was conducted at the wet markets and at the remote locations where the source population was identified. Through these efforts, a novel paramyxovirus was found in bats that had been held in wet market conditions; however, the virus was not detected in the free-ranging source population.

In addition to wildlife pathogen surveillance, PREDICT-Indonesia conducted human disease surveillance through a risk-based approach. Priority samples and sample sets were identified through review of archival databases. EVRUE identified archived sample sets from cases of fever of unknown origin that tested negative for normative diagnostics (e.g. dengue fever and malaria) and individuals who were at a high risk for zoonotic pathogen exposure. Also, PREDICT obtained approximately 400 archived samples collected from populations in Bandung, Papua, Sulawesi, Java, Borneo, Bali, and Sumba that were found to have a higher risk of exposure to zoonotic pathogens. A number of these samples originated from febrile patients that had direct contact with wildlife through hunting and consumption and indirect contact with wild animals in and around their home.

**Testing**

Wildlife samples collected from PREDICT priority taxa were tested for arenaviruses, coronaviruses, filoviruses, flaviviruses, hantaviruses, henipaviruses, influenza, paramyxoviruses, poxviruses, retroviruses, rhabdoviruses, and seadornaviruses. Human samples were tested for seadornaviruses, paramyxoviruses, arenaviruses, hantaviruses, coronaviruses, henipaviruses, phleboviruses, filoviruses, rhabdoviruses, herpesviruses, orbiviruses, and enteroviruses.

**DISCOVERY OF NOVEL VIRUSES INCLUDING A NEW PARAMYXOVIRUS IN FRUIT BATS**

PREDICT-Indonesia detected a number of viruses in wildlife specimens, many of which were new. One notable finding was a new paramyxovirus found in fruit bats being sold in a wet market for food in Northern Sulawesi. Phylogenetic analysis places this new virus between the known viruses in the genera Rubulavirus and Respirovirus groups. There is currently no evidence this virus is zoonotic. Further characterization of the virus’ genome is needed to determine if this virus may be transmissible to people or pose a risk to human health, as is more extensive testing of fruit bat specimens collected from this region to better understand the prevalence of the previously undescribed virus in wild free-ranging and market populations of fruit bats.

**DISEASE OUTBREAK RESPONSE AND PREPAREDNESS**

PREDICT-Indonesia assisted local and international partners in outbreak response and preparedness. Examples of outbreak efforts included:
• In response to H7N9 outbreaks in China, PREDICT-Indonesia attended government meetings to provide technical insight towards influenza virus preparedness.

• The PREDICT Indonesia Country Coordinator was invited by the Director of Animal Health Services to serve as an expert in a discussion regarding health requirements for nonhuman primate importation to Indonesia. This review led to a more standardized operating procedure for importation.

• PREDICT-Indonesia presented on project activities at a cross-sectoral meeting on laboratory diagnostics for zoonoses control, which was organized by the Ministry of Health, the Center of Research & Development for Disease Vector and Reservoir in Salatiga, supported by WHO, FAO, and USAID. Participants included government/national diagnostic labs for animal and public health, as well as universities and research institutes. PREDICT provided a source of technical support and expertise for the country’s National Committee on Zoonoses and Emerging Infectious Diseases (KomNas Zoonosis Control).

• The Country Coordinator was appointed as a Member of the Expert and Academia Panel in the committee for the National Commission of Zoonosis Control to ensure representation from PREDICT.

• PREDICT-Indonesia also assisted the government with follow-up investigation on research conducted by an Indonesian scientist that suggested Ebola virus exposure in orangutans. The PREDICT Indonesia laboratories (IPB and Eijkman) confirmed through additional analysis on specimens remaining from the study that samples did not originate from orangutans as suggested in the published manuscript. The Ministry of Forestry’s Directorate of Biodiversity Conservation and PREDICT wrote a letter to the journal editor to notify them of these findings.

REFERENCES