excerpted from
Reducing Pandemic Risk, Promoting Global Health

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On the list of the ten most biologically diverse countries in the world, Peru boasts a rich variety of ecosystems, species, genetic resources, and cultures (Mittermeier et al. 1997). Cutting through the country from North to South, the Andes mountain range determines Peru’s variety of habitats and high degree of biodiversity heterogeneity (Brack and Mediola 2000). However, despite the natural treasures present, Peruvian biological wealth is ignored and overharvested. Rapid economic and demographic growth occurred in recent years, driving major ecological changes that are especially noticeable in the Amazon forest. The main activities leading to biodiversity loss are deforestation, agricultural expansion, and extractive industries, which have facilitated illegal logging and wildlife trade. These anthropogenic impacts are becoming more apparent and threatening, and there are clear examples in Peru of a link between these impacts and the emergence of infectious diseases in people.

Mining is exerting a powerful force for change in the Peruvian Amazon. Between 1999 and 2012, the geographical area impacted by mining expanded by 400% in Madre de Dios, one of the most biodiverse regions of the world (Asner et al. 2013). As a result of the global financial crisis in 2008 and the high international price of gold, a “gold rush” exponentially affected Amazon territory, with losses in forested areas increasing from 2,166 to 6,145 hectares per year (Asner et al. 2013). Deforestation, driven by human economic activities, is also prevalent in much of the Peruvian territory. For example, land conversion for oil palm crops, fueled by the biodiesel industry, is increasing in the northeastern Peruvian Amazon (Dammert et al. 2012).

These changes have a direct impact on biodiversity, causing loss of species and alterations in the ecological balance of ecosystems. With over 500 native species of mammals, Peru is the third most diverse country in the Americas and the fifth in the world (Pacheco et al. 2009).

Despite efforts by officials to develop policy prohibiting wildlife trade, this activity is still rampant throughout Peru and especially prevalent in wet markets.

PHOTOS BY PATRICIA MENDOZA

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Mammals in Peru are largely dominated by bats (165 species) and rodents (162 species), representing 64% of all species. An equal diversity of pathogenic microorganisms related to these mammalian hosts, many of them potentially zoonotic, can be expected. Disease outbreaks stemming from bat and rodent reservoirs heavily burden the health and welfare of human populations in remote areas. The expansion of sugar cane crops and associated migrant labor caused changes in the ecology of rodents and vectors in Peru’s northwest area, sparking outbreaks of plague in 2010 (Pachas et al. 2010). Similarly, sylvatic rabies caused by vampire bats dramatically affects indigenous communities with poor access to health services throughout the Peruvian Amazon (Condori et al. 2013).

Furthermore, as a highly diverse country, Peru is also an active supplier for the international market of wild pets, both by legal and illegal means (Ríos et al., 2008). Despite international agreements and ongoing efforts at the national and regional levels for the development of policies that prohibit wildlife trade, this activity is still rampant throughout Peru and especially prevalent in wet markets (Gastañaga et al., 2010; Ortiz, 2010; Ríos et al. 2008).

The aforementioned anthropogenic pressures increase Peru’s vulnerability to the emergence of zoonotic diseases of wildlife origin. Strengthening government capacities, particularly for disease surveillance strategies that allow for predicting disease occurrence and identifying high-risk interfaces for zoonotic transmission, is necessary. To this end, the PREDICT project was implemented in Peru from 2010 to 2014 as a collaborative effort between the Wildlife Conservation Society (WCS), the Peruvian Veterinary Service (SENASA), and the Peruvian Institute of Health (INS). PREDICT’s strategy for improved detection and prevention of zoonotic diseases takes a One Health approach, recognizing that human activities and the health of humans, animals, and the environment are linked. Wildlife disease surveillance in Peru was focused on the detection of pathogens that can spread through subsistence hunting practices or be introduced to urban environments through the wildlife trade at wet markets. The approach was expanded to include active surveillance for novel pathogens in bats and rodents in and around human dwellings and in wildlife targeted for disease control and zoonotic outbreak investigations by government partners.

**PARTNERS**
The PREDICT Peru team was a collaborative effort between the Wildlife Conservation Society (WCS), the Peruvian Institute of Health (INS), USAID, and the Peruvian Animal Health Service (SENASA).

Other local partners included:

- School of Veterinary Medicine, Universidad Nacional Mayor de San Marcos
- US Naval Medical Research Unit Six (NAMRU-6)
- General Directorate of Epidemiology, Ministry of Health
- General Directorate of Forestry and Wildlife, Ministry of Agriculture
• Regional governments of Loreto and Ucayali
• Universidad Nacional de Tumbes
• Zoo Parque Natural de Pucallpa, Ucayali
• Varillal Temporary Custody Center, Loreto
• Ikama Peru Rescue and Rehabilitation center, Amazonas
• Taricaya Rescue Center, Madre de Dios
• Amazon Shelter Rehabilitation and Rescue Center, Madre de Dios

MAJOR ACHIEVEMENTS
• Enhanced capacity and improved cooperation among agencies, which led to implementation of effective health surveillance strategies and policy on a national scale. PREDICT’s strategies for surveillance and laboratory procedures were implemented by INS nationwide (see Success Stories for more information).

• Enhanced reporting of domestic animal die-offs at markets to SENASA through a network of collaborators trained through PREDICT.

• Improved networks for disease communication and response among key government agencies, scientific institutions, and people at risk and formalized agreements with partners to ensure sustainability of the PREDICT One Health approach for wildlife disease surveillance and research.

• Developed capacity to conduct PCR using PREDICT protocols on human and animal samples in INS laboratories and expanded the suite of pathogens for screening during outbreak investigations.

• In cooperation with the Peruvian Directorate of Forestry and Wildlife (DGFFS), published guidelines for and assisted with management and sampling of wildlife confiscated from the illegal wildlife trade.

• Engaged stakeholders in the national wildlife disease surveillance system (VEAS) managed by SENASA.

• Highlighted the importance of wildlife disease surveillance at human-animal interfaces with high-risk for disease transmission by detecting a broad range of zoonotic pathogens.

SUCCESS STORIES

Enhanced Capacity and Improved Cooperation with and among Governmental Agencies

PREDICT significantly enhanced local capacity to detect and prevent zoonotic diseases of wildlife origin in Peru. A key indicator of success is the high level of trust and collaborative goodwill generated with the central government (i.e. Ministry of Health and SENASA). This enhanced cooperation was illustrated by the degree of engagement and participation of leaders and decision-makers in workshops for strengthening government capacity for wildlife disease surveillance, building upon SENASA’s existing wildlife disease monitoring network. Surveillance
of wildlife-borne pathogens at wildlife-human interfaces was a high priority for the Peruvian government. As a result, PREDICT’s strategies for improving surveillance and diagnostic laboratory capacities in Peru were adopted as a joint initiative by INS in 2011 and formally incorporated into the INS Strategic Operational Plan in 2013. Accordingly, the following strategies were adopted and implemented on a national scale:

- Pathogen detection at wildlife-human interfaces with high-risk for disease transmission (wildlife for sale in wet markets, wildlife in zoos and rescue centers, and subsistence hunting of wildlife);
- Viral pathogen surveillance in peri-urban wild animal reservoirs (bats and rodents); and
- Capacity building at the INS laboratory for consensus (virus genus/family level) PCR.

PREDICT Staff Member Awarded the 2014 Pedro N. Acha Award for Excellence

Micaela De La Puente from the PREDICT Peru team was awarded the 2014 Pedro N. Acha Award for Excellence in Veterinary Public Health on behalf of her thesis “Zoonotic Enteric Bacteria in Captive Neotropical Primates from Perú” (“Bacterias Entéricas con Potencial Zoonótico en Primates Neotropicales Mantenidos en Cautiverio, Perú”) in recognition of her dedication to the highest standards of study and professionalism in the veterinary health field in her early career. She received the award in a public ceremony in Washington, D.C. on September 29, 2014 (http://www.pahofoundation.org/en/news/411-winners-of-awards-for-excellence-in-public-health-announced-awardees-hail-from-argentina-bolivia-mexico-peru-and-the-united-states.html). This award is one of six Awards for Excellence in Inter-American Public Health, given by the Pan American Health Organization (PAHO) and the PAHO Foundation since 1975, recognizing the excellence in various areas of health that are vital to Americas. Dr. De La Puente’s undergraduate thesis demonstrated the presence of zoonotic bacteria in 19% of neotropical monkeys in wetmarkets, wildlife refuges, and zoos in Peru, illustrating the potential health threat that monkeys removed from their environments and placed in poor housing conditions can pose to humans.

CAPACITY BUILDING

Training

In order to develop a sustainable surveillance system, PREDICT provided training in wildlife sampling and surveillance methods to 346 people in Peru, including field staff; veterinarians; laboratory technicians; biologists; indigenous community residents; and personnel from the public health, veterinary, and other government sectors. Standardized methods and innovative
tools were developed to ensure proper collection of information and samples at high-risk human-wildlife interfaces. Training topics included biosafety, animal capture, proper data and sample collection, cold chain, sample packing and shipment, and laboratory safety. Biosafety was emphasized to reduce occupational hazards to field and laboratory personnel. Questionnaires were completed at the end of each training session to ascertain knowledge transfer.

Diagnostic Laboratory Capacity

Diagnostic capacity was established at INS laboratories for screening bat, primate, and rodent samples for 12 viral genera/families of pandemic potential using broadly reactive consensus PCR assays (alphaviruses, arenaviruses, bunyaviruses, henipaviruses, coronaviruses, filoviruses, flaviviruses, hantaviruses, orthomyxoviruses (influenza), paramyxoviruses, retroviruses, and rhabdoviruses).

SURVEILLANCE

Surveillance was conducted in priority wildlife taxonomic groups (i.e. bats, nonhuman primates, and rodents) at critical wildlife-human interfaces with high risk for disease transmission in Peru (Figure 1 and Table 1) with a focus on wildlife hunted for subsistence by indigenous communities, wildlife for sale in wet markets or confiscated in the wildlife trade.

Figure 1. Sites where PREDICT conducted virus surveillance in wildlife taxa at high-risk disease transmission interfaces between wildlife and humans.
wildlife in captive settings (sanctuaries, rehabilitation centers, and zoos), and wildlife in peri-domestic settings (i.e. in and around human dwellings or fields). In addition, PREDICT conducted surveillance in wildlife during disease outbreaks in people. Free-ranging wild animals were also sampled in remote areas without human disturbance for baseline comparison.

A total of 80 sampling events were conducted in Peru, with 1,433 rodents, 535 nonhuman primates, 170 bats, and 667 animals from other taxa sampled for pathogen screening (Figure 2). Collection of blood samples on filter paper (e.g. dried blood spot cards) and in sample preservation solutions were employed to collect and preserve samples in remote locations where maintenance of a cold chain in the field was not feasible.

In order to ensure sustainability, PREDICT facilitated communications and forums to streamline national strategies for wildlife disease surveillance. Partnerships were formalized with seven institutions including ministries, laboratories, academia, NGOs, and civil organizations. PREDICT provided guidance and assistance to government agencies in more than 12 surveillance efforts; notable examples include bat and rodent sampling campaigns conducted during disease control programs and a number of disease outbreak investigations (e.g. vampire-bat rabies in Loreto, leptospirosis in Ucayali, and plague in Cajamarca). Key counterparts

### Table 1. Number of animals sampled according to targeted transmission interfaces.

<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>In and near human dwellings</td>
<td>28</td>
<td>1226</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>Hunted wildlife</td>
<td>83</td>
<td>69</td>
<td>0</td>
<td>175</td>
</tr>
<tr>
<td>Markets</td>
<td>97</td>
<td>103</td>
<td>0</td>
<td>329</td>
</tr>
<tr>
<td>Wildlife trade</td>
<td>110</td>
<td>3</td>
<td>0</td>
<td>107</td>
</tr>
<tr>
<td>Zoos and sanctuaries</td>
<td>216</td>
<td>14</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Pristine habitat</td>
<td>1</td>
<td>18</td>
<td>158</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>535</strong></td>
<td><strong>1433</strong></td>
<td><strong>170</strong></td>
<td><strong>667</strong></td>
</tr>
</tbody>
</table>

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(market vendors and staff from parks, zoos, and rescue centers) were committed to reporting animal disease events at wildlife-human interfaces and were instrumental in establishing a wildlife disease surveillance network. Surveillance in free-ranging bats and rodents was conducted in collaboration with scientific institutions, including the Natural History Museum of Arequipa and Universidad Mayor de San Marcos.

OUTBREAK RESPONSE AND PREPAREDNESS
PREDICT also improved capacity for outbreak response in Peru by providing training and assistance to government agencies during field investigations. PREDICT aided the INS national task force in epidemiological surveillance in Peru during three zoonotic disease outbreaks associated with wildlife. Response efforts were focused on active disease surveillance in urban and peri-urban animal reservoirs and training of field staff from public agencies, universities, and NGOs on wildlife sampling and disease reporting.

Specifically, public health and veterinary agencies, including INS, the Regional Directorate of Health of Loreto, the Regional Directorate of Environmental Health of Ucayali, and SENASA reached out to PREDICT for assistance with wildlife sample collection and laboratory diagnostics during the following outbreaks:

- Pneumonic plague in Cajamarca and La Libertad in northwestern Peru from 2010 to 2013;
- Hantavirus pulmonary syndrome in Iquitos in the Loreto Region in 2011 (second historic record in country); and
- Leptospirosis in Pucallpa in the Ucayali Region in 2011.

INVESTIGATION OF ZOONOTIC PATHOGENS IN HUNTED WILDLIFE
PREDICT contributed to a number of studies investigating the presence of zoonotic pathogens in hunted wildlife in Peru. Arboviruses cause significant illness and death in South America, yet sylvatic cycles and the role of wildlife in the ecology of these viruses is still poorly understood. Outbreaks of disease in wildlife preceding human cases of yellow fever have been recognized in Brazil and Panama, suggesting linked transmission of this virus between wildlife and human populations. PREDICT aided in assessing exposure (i.e. serologic antibody titers) of hunted wildlife and domestic animals to flaviviruses and alphaviruses in a wildland-rural interface in the northeastern Peruvian Amazon where humans, animals, and vectors have close interaction. Results indicated that ungulates had the highest exposure to flaviviruses and alphaviruses followed by rodents and edentates (i.e. anteaters and sloths; Mayor et al. 2013). Specifically, ungulates had high antibody titers against St. Louis Encephalitis Virus (SLEV) and yellow fever virus (YFV). Rodents had high titers against Venezuela Equine Encephalitis Virus and SLEV, and edentates expressed high antibody titers against YFV and SLEV. In addition, animals sampled at the relatively disturbed site (i.e. high deforestation and encroachment of land for agricultural use and cattle ranching) had higher exposure.
compared to the more pristine site, suggesting a higher risk of arbovirus infection in areas undergoing land-use change (Mayor et al. 2013).

PREDICT also assisted with research that explored the occurrence of *Toxoplasma gondii* exposure (a zoonotic parasite) among hunted peccaries, brocket deer, and lowland tapir in the Peruvian Amazon as a model for pathogen sharing. For this study, blood spot samples were obtained from animals hunted in the area surrounding the community of Nueva Esperanza where human cases of ocular toxoplasmosis had been documented. Evidence of exposure was common in the hunted ungulates (17-40%), suggesting a potential source of *T. gondii* infection in this community (Aston et al. 2014). Seroprevalence was lower in this study relative to other surveys of wild ungulates in less remote locations in the Amazon with domestic and feral cats.

**REFERENCES**


