excerpts from
Reducing Pandemic Risk, Promoting Global Health

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In Tanzania, human livelihoods are often directly dependent on natural resources. Rapid population growth has increased land-use change, the demand for natural resources, and the potential for contact between wildlife and people. Tanzania has diverse wildlife-livestock-human interfaces, which offer ideal targets for zoonotic disease surveillance. Tanzania is home to millions of wild animals, many of which migrate across borders to other countries and ecosystems. Ongoing human and environmental changes are altering landscapes and connections between people and animals. For example, in the more arid areas of the Rift Valley, which join the Congo Basin in the west, water diversion and land conversion for agriculture coupled with continued population growth are restricting once vast livestock grazing areas for traditional livestock keepers (Copolillo et al. 2008; Walsh 2012). The result is an increase of livestock populations on remaining grazing land, often bordering villages and wildlife protected areas. The increasing density of livestock near wildlife-rich protected areas coupled with water scarcity may change the dynamics of current zoonotic threats and may facilitate transmission of diseases of pandemic potential across this interface (Mazet et al. 2009). Additionally, Tanzania possesses many islands of rainforest habitat, most notably the Eastern Arc Mountains, which are biodiversity hotspots due to the high degree of endemism and small mammal diversity (Burgess et al. 2007). These remnant forests provide an exceptional opportunity to assess zoonotic pathogen potential in rodent, bat, and primate species. Rapidly growing urban centers like Dar es Salaam on the Indian Ocean coast present another unique environment where pathogens from bats and rodents have the potential to be transmitted to and spread in dense human populations.
Despite the wealth of biodiversity and close interaction of human and animal populations at these interfaces, Tanzania’s capacity to conduct wildlife disease surveillance at the regional and national level is still developing. Existing collaborations between Sokoine University of Agriculture (SUA) and the ministries and institutions responsible for livestock, wildlife, and human health enabled the PREDICT team to increase and expand wildlife surveillance activities at high-risk wildlife-livestock-human interfaces throughout the country. These collaborations were strengthened through PREDICT surveillance work, as well as capacity building activities, in partnership with the Tanzania Wildlife Research Institute and other local stakeholders.

The PREDICT Project in Tanzania, in collaboration with in-country partners, conducted active surveillance of viruses of wildlife at critical human-wildlife interfaces. Thorough site assessment and sample collection from diverse bat, rodent, and nonhuman primate species allowed the PREDICT team to examine the potential for zoonotic transmission at many high-risk disease transmission interfaces.

**LOCAL PARTNERS**

In Tanzania, PREDICT established partnerships with national ministries, universities, and NGOs to conduct surveillance activities and inform key stakeholders on progress on a quarterly basis. Partners in Tanzania and East Africa included:

- Sokoine University of Agriculture (SUA)
- USAID
- Ministry of Livestock and Fisheries Development
- Ministry of Health and Social Welfare
- Ministry of Natural Resources and Tourism
- Tanzania Wildlife Research Institute (TAWIRI)
- Tanzania National Parks (TANAPA)
- National Institute of Medical Research (NIMR)
- Muhimbili University of Health and Allied Sciences
- Central Veterinary Laboratory and Regional and District Veterinary Offices
- Centers for Disease Control and Prevention Laboratory, Dar es Salaam
- Centers for Disease Control Global Disease Detection Group, Nairobi, Kenya
- Makerere University Walter Reed Project (MUWRP), Uganda
MAJOR ACHIEVEMENTS

• Implemented the first systematic and national-level viral surveillance approach for wildlife in Tanzania (see Success Stories for more information).

• Trained a One Health Workforce by providing a variety of educational and training opportunities at multiple levels (see Success Stories for more information).

• Developed and refined the PREDICT local media surveillance system to identify reports of human and animal disease in local Tanzanian news sources not currently integrated into digital disease detection systems like HealthMap, providing proof of concept for the expansion of local media surveillance to seven other PREDICT countries.

• Partnered with CDC representatives and local district chief medical officers to plan paired human-animal surveillance activities at sugar cane plantations in central Tanzania. Pilot data from this collaboration will provide information on the risk of viral transmission from rodents to sugar cane plantation workers and could spur future One Health programs.

• Conducted 319 active wildlife sampling events, and collected samples from a total of 1,753 animals (650 bats, 632 rodents, 251 nonhuman primates, and 220 samples from other taxa, primarily samples collected from bushmeat).

• Developed the first viral detection laboratory for wildlife in Tanzania, trained laboratory technicians at Sokoine University of Agriculture (SUA) in consensus-based PCR diagnostics, and initiated screening for arenaviruses, a high priority viral family due to the detection of novel arenaviruses in commensal rodents in Tanzania.

• Increased government, non-governmental organization, and community stakeholder awareness of approaches to prevent disease transmission at human-wildlife interfaces through presentations and distribution of calendars with educational messages on zoonotic diseases.

• With support from the Emerging Pandemic Threats DELIVER project, installed a liquid nitrogen generating plant in south-central Tanzania to strengthen cold chain for biological materials and wildlife samples to enhance local disease surveillance activities.

SUCCESS STORIES

Building SMART Surveillance in Tanzania

PREDICT implemented the first systematic and national-level viral surveillance approach for wildlife in Tanzania, improving awareness of high-risk human-animal interfaces, targeting animal sampling in key taxa at prioritized sites representing Tanzania’s biological and geographic diversity and building the infrastructure and human resource base for the detection of emerging pathogens of pandemic potential.

Further, PREDICT-Tanzania partnered with diverse stakeholders at multiple levels of Tanzanian health systems, including community game officers, health workers, livestock extension officers, university researchers, veterinary professionals, and ministry level officials to characterize disease transmission risk, conduct wildlife surveillance activities, and share results. In Tanzania, PREDICT incorporated indigenous knowledge and participation, local media systems, and online intelligence to design and optimize surveillance activities reflecting the country’s broad ecological and behavioral diversity.
In 2009, preliminary capacity assessments identified few national and donor investments in wildlife disease surveillance, and those that did exist primarily emphasized known diseases of conservation concern. Outside of major urban centers, limited infrastructure existed to support collection of wildlife samples for molecular diagnostics. By January 2014, liquid nitrogen cold chain capability was extended to central areas of the country, and personnel from universities, the Tanzania Wildlife Research Institute (TAWIRI), government health workers, veterinary and livestock extension officers, and community members were trained and actively participated in the identification of priority human-animal interfaces and in safe animal capture and sampling of high-risk wildlife groups.

**Strategic.** Working at the community level with village councils, elders, government representatives, and wildlife professionals and at the global level through real-time disease outbreak alerts, PREDICT-Tanzania characterized human-animal interfaces by type of risk and strategically prioritized interfaces for surveillance to ensure coverage of high-risk taxonomic groups and a diversity of human-animal contact.

**Measurable.** PREDICT-Tanzania successfully sampled over 1700 animals from 12 areas in Tanzania representing diverse interfaces for human-animal contact and engaged with stakeholders in surveillance and risk reduction activities. PREDICT-Tanzania also tested priority specimens from over 1,200 individuals, building the first baseline data on potential emerging viral threats from wildlife to vulnerable populations.

**Adaptive.** PREDICT-Tanzania used site assessments and feedback from diverse stakeholders to support and adapt surveillance to interfaces and locations of highest risk for disease emergence and spillover. Surveillance of local media sources also identified disease reports, risky behaviors, and human-animal contact used to adapt surveillance strategies.

**Responsive.** PREDICT-Tanzania cooperated closely with local and regional partners to coordinate surveillance with existing wildlife, livestock, and human disease surveillance and monitoring activities. In collaboration with veterinary researchers from the Tanzania Wildlife Research Institute, PREDICT sampled bats in northern Tanzania’s fragmented forests. At the request of the Centers for Disease Control and Prevention’s Global Disease Detection group, PREDICT sampled rodents in the Kilombero Valley as a first step towards paired human-animal disease surveillance and assessments of viral sharing and occupational hazard in sugarcane plantations.
**Targeted.** PREDICT-Tanzania targeted surveillance at interfaces where people have high contact with key wildlife groups. In close coordination with the surveillance and pathogen detection teams, priority samples from each animal were identified according to interface and potential transmission pathway and tested for viral families representing potential spillover and pandemic threat.

**Training a One Health Workforce**

In Tanzania, PREDICT provided a variety of educational and training opportunities at multiple levels, from community members to university students and health professionals. A total of 110 individuals (74 male, 36 female), including project research staff, were trained in topics ranging from disease surveillance (animal capture and handling, sample collection, and cold chain) to laboratory systems (biosafety, diagnostics, and information management), and disease prevention, enhancing Tanzania’s disease surveillance system and One Health workforce.

PREDICT utilized a cooperative and participatory framework for surveillance site selection, working with local community members and district game and livestock officers to identify locations of wildlife habitat and collect information on human-animal contact to characterize interfaces. In return, PREDICT provided training to an estimated 19 district level officials and community members in zoonotic disease transmission and prevention and on-the-job training in safe animal handling and sampling to multiple high-risk occupational groups (game officers, wildlife professionals, veterinarians, livestock officers, and hunters).

In partnership with RESPOND’s One Health Central East Africa (OHCEA) University Network, PREDICT trained 47 future One Health leaders and scientists from Sokoine University of Agriculture and Muhimbili University of Health and Allied Sciences. Participants received hands-on field training in biosafety, safe wildlife capture and sampling, cold chain management, and One Health surveillance approaches. Training was also conducted in Morogoro, Tanzania at the SUA campus, including an overview of diagnostic methods for detecting zoonotic and emerging disease threats.

PREDICT sponsored staff participation in multiple capacity building opportunities, including:

- Wildlife Capture Africa course in Zimbabwe focusing on the safe use of chemical and physical restraint in wildlife immobilizations.

- Professional exchange and training for Tanzania laboratory technicians from SUA at Makerere University Walter Reed Project (MUWRP) in Uganda on DNA/RNA extraction, PCR, and data management to standardize pathogen detection regionally.

- Molecular diagnostic training for a SUA laboratory technician at the UC Davis One Health Diagnostic and Surveillance Laboratory in California on viral nucleic acid extraction, PCR techniques, consensus PCR viral family testing, and information management.

- One Health Summer School training at Sokoine University of Agriculture organized by Southern African Centre for Infectious Disease Surveillance (SACIDS) focused on the One
Health approach, disease and vector ecology, molecular epidemiology, biosafety, disease surveillance, and outbreak investigations.

- Safe capture, handling, and sample collection training for nonhuman primate disease surveillance with the PREDICT-Rwanda and Mountain Gorilla Veterinary Project field staff.

- Good Clinical Practices courses for researchers at the National Institute for Medical Research (NIMR), organized by Family Health International (FHI) and Kenya AIDS Vaccine Initiative Project (KAVI) Institute.

As a result of these training investments, PREDICT contributed to an enhanced social network of human resources for disease surveillance in Tanzania and encouraged greater transdisciplinary cooperation in the health system among Tanzania’s future leaders and scientists.

**CAPACITY BUILDING**

**Infrastructure improvements**

At the Sokoine University of Agriculture’s Faculty of Veterinary Medicine in Morogoro, Tanzania, PREDICT developed the first viral detection laboratory for wildlife in the country. The laboratory is equipped with trained personnel and advanced molecular technology to screen wildlife samples for known and unknown viruses within priority viral families (e.g., arenaviruses) and genera of potential pandemic potential and is networked to regional and global laboratory diagnostic centers of excellence in Uganda and the US for support and confirmatory testing. Technicians at the SUA lab regularly consult and engage in refresher trainings with mentors in the US with telemedicine-based knowledge and skill transfer, enabling acquisition and adoption of new techniques, protocols, and diagnostic testing on demand.

Additionally, with support from the EPT program partner DELIVER, PREDICT-Tanzania strengthened capacity for disease surveillance, sample collection, and storage through installation of a liquid nitrogen generating plant, the sole source of liquid nitrogen in the South-central area. The liquid nitrogen generator provides the means for maintaining cold-chain during sampling efforts and has enhanced capacity for other surveillance activities in Tanzania.

**Operationalizing One Health**

One Health research and disease surveillance capacity was improved nationally in cooperation with 10 partner organizations and agencies, including the Tanzania Wildlife Research Institute (TAWIRI), and through training programs to improve wildlife surveillance and disease diagnostics. Sharing of PREDICT activities and results with National Institute for Medical Research, Ministry of Livestock and Fisheries Development, and Tanzania Wildlife Research.
Institute increased discussion and awareness of wildlife viral surveillance and detection, promoting opportunities for future one health surveillance initiatives.

PREDICT-Tanzania also worked with Sokoine University of Agriculture and the Health for Animals and Livelihood Improvement (HALI) project to expand the One Health Workforce in Tanzania through a center of excellence in ecosystem and wildlife health. PREDICT and RESPOND in Tanzania effectively catalyzed wildlife health momentum at Sokoine University, where plans are in place to offer a new master’s program in wildlife and ecosystem health, building on current graduate programs in One Health and molecular biology supported though the Southern African Centre for Infectious Disease Surveillance (SACIDS). Through these programs, veterinary medicine, agriculture, animal science, forestry, wildlife, and social science expertise will support transdisciplinary education and training using a One Health approach, with options for field-based training at the HALI project Iringa station, PREDICT Tanzania’s surveillance team base. This center will provide a long-term training ground for students, faculty, researchers, and government personnel in One Health approaches to solving complex problems and will foster and encourage greater local, regional, and national cooperation and coordination of surveillance and health research.

SURVEILLANCE
PREDICT conducted wildlife surveillance at a number of high-risk wildlife-human contact interfaces in the following areas in Tanzania (Figure 1):

- South-central (Eastern Arc Mountains – Udzungwa Mountains National Park and surrounding forest reserves and villages, Kilombero Valley, Ruaha National Park and surrounding areas, Mbeya region, and Mbinga district)
- North-west (Geita – Industrial and artisanal mining areas)
- North-east (Eastern Arc – Amboni caves, Tanga region, and surrounding areas)
- Eastern (Coastal, Dar es Salaam and surrounding areas, Morogoro, and Mtwara)

High-risk interfaces targeted for wildlife pathogen surveillance in Tanzania included (Figure 2; Table 1):

1. Hunting/bushmeat interfaces where wild animals, most commonly rodents, ungulates, and carnivores, are consumed after being hunted, killed, and slaughtered under poor sanitary conditions;
2. Crop raiding interfaces where wild animals interact with humans by feeding on crops in local agricultural fields or in fruit and vegetable markets;
3. Peri-domestic settings and areas near extractive industries where wild animals (i.e. rodents and bats) commonly interact with humans in and around dwellings, villages, urban centers, and work sites or camps;
4. Ecotourism interfaces where tourists from around the world travel to see wildlife in unique environments including savannas, forests, mountains, and caves; and
5. High traffic interfaces where construction of infrastructure including roads, railways, and buildings has enhanced human encroachment into wildlife habitat, and the rapid flow of people could facilitate rapid spread of zoonotic pathogens.
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>Agricultural settings</td>
<td>17</td>
<td>247</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ecotourism and recreational activities</td>
<td>30</td>
<td>0</td>
<td>59</td>
<td>0</td>
</tr>
<tr>
<td>Extractive industries</td>
<td>0</td>
<td>0</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>In or near human dwellings</td>
<td>22</td>
<td>306</td>
<td>543</td>
<td>7</td>
</tr>
<tr>
<td>Hunted wildlife</td>
<td>4</td>
<td>70</td>
<td>0</td>
<td>195</td>
</tr>
<tr>
<td>Wildlife preying on livestock or their food</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Wildlife raiding markets</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Protected areas</td>
<td>122</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other high-risk interfaces</td>
<td>56</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>251</strong></td>
<td><strong>632</strong></td>
<td><strong>650</strong></td>
<td><strong>220</strong></td>
</tr>
</tbody>
</table>

**Bushmeat hunting and consumption project.** The PREDICT Tanzania team launched a bushmeat surveillance study in the Ruaha Ecosystem of South-central Tanzania within nine villages where both legal and illegal hunting are practiced. Working with a community surveillance network, PREDICT collected muscle and organ tissue samples from over 200 fresh-killed wild animals. The study revealed that consumption of bushmeat in the area is very common, with animals hunted and slaughtered under poor sanitary conditions, which may expose hunters to wildlife pathogens. Specimens from hunted animals will be tested for priority viral families using the consensus PCR approach. Additionally, we are conducting a survey of hunters and bushmeat consumers in the villages to assess the behavioral and socioeconomic factors associated with subsistence poaching in the area. Data obtained from this study will improve the understanding of the subsistence poaching in the area along with factors potentially implicated in zoonotic disease transmission risk.

**DISEASE OUTBREAK RESPONSE AND PREPAREDNESS**

The PREDICT Tanzania team communicated with the Tanzania Wildlife Research Institute (TAWIRI), Ministry of Health and Social Welfare, and Ministry of Livestock and Fisheries Development to offer support in investigating numerous outbreaks in wildlife, domestic animal, and human populations, including outbreaks of African Swine Fever in Mbeya, undiagnosed illnesses in people in Gombe, and an outbreak of unknown origin killing goats and chickens on Musira Island in Bukoba. PREDICT surveillance and diagnostic support was not utilized in outbreak investigation and response efforts, but communications were strengthened with government partners on integrating PREDICT wildlife disease investigation support in national disease outbreak response planning.

The PREDICT Tanzania team collaborated with Tanzania National Parks (TANAPA) to jointly sample giraffe in Ruaha National Park, which were showing signs of an undiagnosed skin disease. PREDICT and TANAPA worked together to use advanced molecular diagnostics (deep sequencing) to identify the cause of this disease.
PREDICT Tanzania director Professor Rudovick Kazwala (bottom right) works with a team of researchers from Tanzania National Parks and Sokoine University of Agriculture to safely collect samples from an anesthetized giraffe.

REFERENCES


