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Kerri Pedersen
United States Department of Agriculture, Kerri.Pedersen@aphis.usda.gov

John A. Baroch
USDA/APHIS/WS National Wildlife Research Center, john.a.baroch@aphis.usda.gov

Dale L. Nolte
USDA-APHIS-Wildlife Services, Dale.L.Nolte@aphis.usda.gov

Tom Gidlewski
National Wildlife Disease Program, Thomas.Gidlewski@aphis.usda.gov

Thomas J. Deliberto
USDA/APHIS/WS National Wildlife Research Center, Thomas.J.DeLibertot@aphis.usda.gov

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KERRI PEDERSEN, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Disease Program, Fort Collins, CO, USA
JOHN A. BAROCH, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Disease Program, Fort Collins, CO, USA
DALE L. NOLTE, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Disease Program, Fort Collins, CO, USA
THOMAS GIDLEWSKI, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Disease Program, Fort Collins, CO, USA
THOMAS. J. DELIBERTO, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Disease Program, Fort Collins, CO, USA

ABSTRACT The National Wildlife Disease Program (NWDP), overseen by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (WS), was established in 2003 to develop a nationally coordinated wildlife disease surveillance and emergency response system. Since its inception, the NWDP has developed collaborations with over 200 national and international partners. The national partners include state, tribal, federal, and private organizations. These partnerships have resulted in surveillance and management of over 100 pathogens, toxins, and disease syndromes affecting wildlife, domestic animals, and humans. Several of these pathogens, including avian influenza, plague, tularemia, bluetongue, and 10 pathogens carried by feral swine, are monitored on a national or regional scale. The NWDP maintains an archive of select wildlife disease samples. Archived samples are available to scientists at universities and other entities with approved research protocols. The NWDP also serves as Wildlife Services' primary emergency response unit. The program's wildlife disease biologists are trained as all-hazard first responders, and the national office coordinates training and mobilization of these and other personnel. Internationally, the NWDP has worked with over 30 countries, developing close relationships with many organizations. This paper provides an overview of the NWDP structure and its activities. Programmatic efforts to address highly pathogenic avian influenza (HPAI) H5N1 are presented as an example of a coordinated national response when a disease risk posed by wildlife presents a potential threat to agriculture or humans.

KEY WORDS archive, disease, National Wildlife Disease Program, surveillance, USDA, wildlife.

INTRODUCTION

West Nile virus (WNV) disease emerged in New York City during the summer of 1999 and by 2002 had crossed the continent and reached California. The initial outbreak and subsequent spread of WNV revealed weaknesses in the U.S. public health infrastructure in responding to a wildlife-borne disease. A report by the RAND Corporation (Soto et al. 2005) assessing the response to the outbreak noted that poor communication and widely varying surveillance, detection, and reporting protocols were common. It was concluded that during zoonotic disease outbreaks it is vital to establish working relationships between various elements of the health community, and that new partnerships beyond the traditional public health arena (e.g., agriculture and veterinary communities) were needed to improve disease surveillance and response at the local, state, and federal levels. The Severe acute respiratory syndrome (SARS) and Monkey pox outbreaks, foot-and-mouth disease (FMD) outbreak in Great Britain, and incidences of chronic wasting disease, plague, tularemia and other diseases (DeLiberto and Beach 2006) further illustrated the need to integrate animal and wildlife disease expertise into the public health system.

The U.S. Department of Agriculture (USDA) recognized this need to coordinate wildlife disease surveillance, standardize diagnostic processes and reporting protocols, and foster collaboration between the human, agricultural animal, and wildlife health communities. In 2003, Wildlife Services (WS), a branch of USDA Animal and Plant Health Inspection Service (APHIS) established the National Wildlife Disease Surveillance and Emergency Response Program, commonly referred to as the National Wildlife Disease Program (NWDP). The establishment of the NWDP foreshadowed a declaration by the Office

International des Epizooties (OIE, World Organization for Animal Health) that "Wildlife Disease Surveillance . . . is the overarching, key element in [transboundary animal diseases] preparedness" (OIE 2004).

When the NWDP was first established in 2003, there were 23 wildlife disease biologists assigned to states throughout the nation with areas of responsibility covering all 50 states. In 2006, an additional 21 disease biologists were added to the NWDP, specifically to lead the sampling effort in each state for the Interagency Early Detection System for Highly Pathogenic Avian Influenza in Wild Birds (DeLiberto et al. 2009). Since NWDP's inception, the role of the wildlife disease biologists is to coordinate disease surveillance at the local level by collecting samples to meet national targets and ensuring that samples are sent to the appropriate laboratory for testing. These disease biologists receive emergency response training for natural disasters, disease outbreaks, or other emergency events and may be mobilized by the NWDP for emergency response. They also collaborate with universities, local laboratories, and other agencies on other diseases of interest (Table 1.) The primary objective of the NRMP, headquartered in Fort Collins, Colorado, is nationally coordinating surveillance programs for several wildlife diseases with agricultural or human health implications, such as avian influenza, several diseases carried by feral swine, plague, tularemia, and bluetongue.

AVIAN INFLUENZA

The NWDP began surveillance for HPAI in wild birds in the spring of 2006. State wildlife agencies and WS' employees collected oropharyngeal and cloacal swabs from various wild bird species and submitted them to local National Animal Health Laboratory Network (NAHLN) facilities for testing as part of a coordinated interagency strategy (USDA 2006). Standardized protocols for sample collection, testing, and reporting were developed and coordinated at the national level. To date more than 275,000 samples have been collected as a result of this surveillance effort.

FERAL SWINE DISEASES

Disease surveillance in feral swine is becoming an increasingly important topic to the NWDP as the range of feral swine continues to expand across the U.S. Currently, samples are collected in 36 states and are tested for 10 diseases or pathogens including both foreign animal diseases (i.e., classical swine fever, African swine fever, foot-and-mouth disease) and endemic diseases (i.e., pseudorabies, swine brucellosis, swine influenza, toxoplasmosis, trichinellosis, porcine circovirus 2, and porcine reproductive and respiratory syndrome). Wildlife disease biologists send some samples directly to the laboratory for testing and others are sent to the NWDP headquarters office for testing, batching, or redistribution to other labs.

Table 1. Examples of the diseases or pathogens that have been coordinated by the National Wildlife Disease Program wildlife biologist.

Disease Surveillance Activities		
Anaplasmosis	Canine Tick Fever	Plague
Avian Cholera	Chikungunya	Q Fever
Avian Pox	Chronic Wasting Disease	Rabies
Babesiosis	*E. coli* 0157	Raccoon Roundworm
Bartonellosis	Eastern Equine Encephalitis	Rocky Mountain Spotted Fever
Big Horn Sheep Pneumonia	Epizootic Hemorrhagic Disease	Salmonella
Bluetongue Virus	Japanese Encephalitis	Toxoplasmosis
Bovine Tuberculosis	Leptospirosis	Trichinosis
Canine Adenovirus	Lyme Disease	Tularemia
Canine Distemper Virus	Neospora	West Nile Virus
Canine Heartworm	Newcastle Disease	White Nose Syndrome

PLAGUE AND TULAREMIA

Wildlife disease biologists coordinate the collection and submission of Nobuto blood filter strips and spatial data from coyotes and other small mammals for plague and tularemia monitoring. Plague monitoring is conducted primarily west of the 100th meridian while tularemia monitoring is conducted nationwide. Samples for these diseases are submitted to the NWDP headquarters where they are batched and submitted to the Centers for Disease Control for testing. Several thousand samples are collected and submitted for plague and tularemia monitoring annually. This monitoring program takes advantage of animals that are selectively removed for wildlife damage management and enables compilation of disease data for various species throughout the United States.

BLUETONGUE & EPIZOOTIC HEMORRHAGIC DISEASE

A pilot project to identify the specific species of biting midges (*Culicoides* spp.) responsible for transmitting bluetongue virus and epizootic hemorrhagic disease was initiated by the NWDP in Indiana and Arizona. Light traps for collection of representative insect species were set for three consecutive nights every other week from May through September 2010. *Culicoides* species were identified and separated and will be tested to determine the presence of both viruses. The NWDP may implement a larger-scale monitoring program after evaluating this pilot program.

BIOLOGICAL SAMPLE TISSUE ARCHIVE

The NWDP headquarters office maintains a wildlife tissue archive. At present, the repository contains more than 275,000 wild bird swab samples and about 75,000 environmental (fecal) samples. The samples have been collected since the spring of 2006 as part of the HPAI surveillance program. On arrival, samples are catalogued and stored in ultra-cold (-80°C) freezers. Researchers with approved protocols are encouraged to request samples for specific research projects that align with the NWDP mission of surveillance and early detection of diseases. In addition, an archive of feral swine serum is maintained at NWDP headquarters. The archive contains approximately 7,500 feral swine samples. Multiple aliquots of serum from each animal are collected and routed to various diagnostic laboratories as well as the archive to be available for future studies. The third component to the archive is a collection of Nobuto strip samples collected primarily from coyotes, a variety of meso-carnivores, and feral swine. Approximately 5,000 of these samples are stored in a freezer (-20°C) and are available to interested researchers.

EMERGENCY RESPONSE

The NWDP serves as WS' primary emergency response unit. The program's wildlife disease biologists are trained as all-hazard first responders, and the national office coordinates training and mobilization of these and other personnel. Wildlife Services has mobilized more than 350 trained biologists for over 50 emergency requests in the last ten years, including: 1) the Deepwater Horizon Oil Spill; 2) five additional oils spills; 3) more than 5 hurricanes including Katrina, Rita, and Ivan; 4) flooding along the Red, Missouri, and Mississippi rivers; and 5) numerous infectious disease emergencies including Newcastle disease, chronic wasting disease, brucellosis, tuberculosis, rabies, plague, *E. coli* 0157, and avian influenza.

All wildlife disease biologists attend a mandatory necropsy course every three years to facilitate recognition of both endemic and foreign animal diseases. Wildlife disease biologists also have training and expertise in personal protective equipment and safety procedures, animal capture, handling and immobilization, biological sampling, communications, and APHIS emergency response procedures. The NWDP also works with the WS Contaminants Response Working Group to train personnel on working in hazardous environments or with contaminated materials, such as wildlife impacted by oil spills.

The NWDP serves as WS' primary contact point to respond to request for emergency assistance. The program's staff monitors an emergency hotline number 24 hours per day, 365 days per year.

INTERNATIONAL ACTIVITIES

The NWDP has become involved in various international activities and capacity building to preemptively address the potential for novel introductions of wildlife diseases and pathogens into North America and more specifically into the United States. Partnerships with Canada and Mexico have been established to assist with and share information on avian influenza surveillance activities. Communication between the three countries will ensure appropriate action will be taken if an introduction of highly pathogenic avian

influenza (HPAI) is discovered. The NWDP has also supported surveillance for HPAI in eastern Russia, Greenland, Mongolia, and China.

The NWDP has collaborated with other federal agencies, universities, nongovernmental organizations, and foreign ministries to conduct workshops on technical aspects of wildlife disease issues. Workshops have covered a variety of topics including fundamentals of diseases and their transmission, on-going ministry activities, wildlife markets, surveillance procedures, safe capture and handling of animals, and biological sampling techniques. Workshops and other activities have been conducted in Argentina, Bangladesh, Brazil, Cambodia, Chile, China, Costa Rica, Indonesia, Lao PDR, Mexico, Philippines, Thailand, and Vietnam. Several activities were regional in scope reaching additional participants from Bhutan, Bolivia, Burma, Canada, Columbia, Ecuador, El Salvador, Guatemala, India, Malaysia, Mongolia, Nepal, Nicaragua, Panama, Paraguay, Peru, Russia, Uruguay, and Venezuela. These workshops have provided technical expertise, and, perhaps most importantly, have encouraged collaboration among human, livestock, and wildlife health sectors.

Collaboration with the Chinese Academy of Sciences has enabled us to host biannual regional conferences on wildlife diseases in Asia, collaborate on surveillance activities for wildlife-borne disease, develop an Asia-Pacific Wildlife Disease Network, and to provide training to increase wildlife disease surveillance capacity for the Chinese State Forestry Administration. Recently, the NWDP initiated a collaborative project with Walter Reed Project-U.S. Army Medical Research Unit in Kenya to create the National Center for Zoonotic Infectious Diseases, which will include a wildlife disease component.

Our international success is primarily due to the dedication, professionalism, and technical expertise of biologists working within the NWDP. International activities frequently require people to work outside of their comfort zone. Language and cultural differences often require use of interpreters and open-mindedness to varying philosophies of natural resource management. Short preparation time and changing agendas are also often incorporated in the challenge necessitating individuals to be flexible. Biologists for the NWDP have taken the domestic "can do" approach frequently exhibited in Wildlife Services and applied it to the international perspective.

A CASE STUDY FOR EMERGENCY RESPONSE AND PREPAREDNESS

In 2006 at the request of the President's Homeland Security Council Policy Coordinating Committee for Pandemic Influenza Preparedness, the U.S. Departments of Agriculture and Interior were asked to develop an interagency strategic plan for early detection of HPAI introduction into North America via wild birds. Once the national plan was developed, each of the four Flyway Councils was encouraged to develop a flyway-specific plan, which was then used by states within the flyways to develop implementation plans.

As part of USDA's implementation of the national and flyway plans, plans were developed between local WS offices and state wildlife agencies, as well as other interested federal, university, and tribal cooperators. Each state was assigned a level 1, 2, or 3 rating, which was determined by a number of criteria including species-specific migratory pathways, historic disease prevalence, the amount of wetland and shoreline, geographic size and location, and the significance of the poultry industry in the state (USDA 2010). The rating corresponded with a target number of samples with level 1 (high risk) states collecting more samples than level 3 (low risk) states. Each state was encouraged to sample from the range of focal species in their state that were considered at highest risk.

The plan encouraged cooperation between agencies that, in many instances, had no previous collaborations. It also served to establish working relationships between field biologists and the local animal health diagnostic laboratory. The development of cooperative alliances was facilitated by a series of small workshops held in Fort Collins in the spring of 2007, which invited state, federal, and tribal agency wildlife biologists, and diagnostic laboratory managers from each state to review the surveillance plan in detail and identify problems and solutions. This proved to be an invaluable forum for fostering collaboration and cooperation among entities at the state level that were unaccustomed to working together as part of a wildlife disease surveillance program on a national scale.

Sample collection procedures including supplies, vials, barcodes, cold chain, and sample submission to

laboratories were standardized. The laboratories used were part of the NAHLN and, as such, had standardized testing protocols. Samples were screened initially using the matrix gene real time reverse transcriptase polymerase chain reaction (rRT-PCR) assay to determine presence or absence of type A influenza (Spackman et al. 2002). Positive samples were tested further with modified H5 and H7 specific rRT-PCR subtyping assays (Spackman et al. 2002). Samples testing positive on either of these assays were forwarded to the National Veterinary Services Laboratories in Ames, Iowa for virus isolation, subtyping, and pathogen testing (DeLiberto et al. 2009).

Since the surveillance program began in 2006, the state-USDA cooperative program submitted more than 275,000 samples for testing. Implementation of this large-scale surveillance program has led to the development of infrastructure for responding to disease outbreaks of avian influenza as well as other emergencies involving wildlife, agriculture, or people. Although no HPAI detections have occurred, development and implementation of the wild bird HPAI early detection system has provided important ancillary benefits toward improved comprehensive wildlife disease surveillance. The number of wildlife biologists trained to investigate morbidity and mortality events, and to conduct active surveillance programs for diseases was increased nationwide. Diagnostic laboratories certified to conduct avian influenza testing as part of the NAHLN were increased improving the capability of the U.S. to rapidly detect introductions of HPAI, as well as other exotic diseases. Enhanced communication protocols for reporting test results of diseases of concern in wildlife were developed and implemented. Critical field equipment necessary for conducting disease surveillance in wildlife and to respond to disease outbreaks was purchased. USDA created a national wild bird tissue archive to provide a resource for future studies on avian influenza and other diseases. Finally, the benefits of improved coordination among wildlife biologists and veterinarians, agricultural veterinarians, laboratory diagnosticians, public health officials, and researchers cannot be underestimated. This coordination has already proved invaluable in detecting, diagnosing, and improving our understanding of the epidemiology of other wildlife diseases (Rue et al. 2010). These enhancements to the wildlife disease surveillance efforts in the U.S. will continue to safeguard the health of wild and domestic animals, as well as the public.

CONCLUSION

The emergence and re-emergence of pathogenic infectious diseases, such as bovine spongiform encephalopathy, FMD, Q fever, bluetongue, Rift Valley fever, Nipah virus, West Nile virus, SARS, HPAI H5N1, plague, and numerous others has increased over the past two decades. The majority (≈ 60%) of these are caused by zoonotic pathogens transmitted along a continuum between wildlife, domestic animals, and human populations (Woolhouse and Gowtage-Sequeria 2005), and were caused by pathogens with a wildlife origin (Taylor et al. 2001).

It is globally recognized that countries conducting disease surveillance in wildlife are more likely to understand the epidemiology of specific infectious diseases and zoonotic outbreaks. These countries are better equipped and prepared to develop solutions that will protect people, agriculture, and wildlife. Consequently, active surveillance for known diseases of economic or public health importance among wildlife is particularly beneficial to national and international interests.

These principles are embodied within the One Health doctrine embraced by organizations such as the United Nation's World Health Organization and Food and Agriculture Organization (FAO), OIE, World Bank, UNICEF, American Veterinary Medical Association, American Association of Wildlife Veterinarians, and the American Medical Association, as well as an increasing number of governments around the world including the U.S. The goal of the One Health concept is to diminish the threat and minimize the impact of epidemics and pandemics due to infectious pathogens of wildlife, domestic animals, and people.

The NWDP was created in support of the One Health concept, and in accordance with Homeland Security Presidential Directives. The strategy of the NWDP is based on a premise that safeguarding the health of humans, animals, and ecosystems makes possible safe agricultural trade, while reducing losses to agricultural and natural resources. The NWDP activities also provide early warning for the emergence and introduction of zoonotic disease that have the potential to cause epidemics or pandemics in people as well as domestic animals and wildlife.

The success of the NWDP is a direct result of its strong partnerships with USDA Veterinary Services,

International Services and Foreign Agricultural Service, U.S. Departments of Homeland Security, Interior, and Health and Human Services, and state agriculture, wildlife, and human health agencies. Additionally, the NWDP has built relationships with over 30 foreign government agencies including Canadian, Chinese, Mexican, and Russian agriculture, health and natural resource agencies, and international organizations, such as FAO, Wildlife Conservation Society, EcoHealth Alliance, and Wetlands International. Building collaborations with these U.S. and foreign government agencies, and nongovernmental organizations has been critical in the development of the NWDP's internationally recognized programs such as the Interagency Highly Pathogenic Avian Influenza Early Detection System for Wild Birds, Canada-U.S.-Mexico Trilateral Highly Pathogenic Avian Influenza Surveillance System, U.S.-China Joint Wildlife Disease Surveillance and Research Program, Plague and Tularemia Surveillance and Early Warning System, and Feral Swine Disease Surveillance Program.

Although the NWDP has already proven extremely successfully in providing domestic and international disease surveillance and emergency response capacity, continuation and enhancement of the wildlife disease surveillance and emergency response systems will be necessary to protect Americans, agriculture, and wildlife from the increasing threat of emerging infectious diseases. Future analyses of the surveillance data will improve our knowledge of diseases in wildlife at large geographic and temporal scales. This knowledge will dramatically improve our ability to assess risks of emerging and re-emerging infectious diseases to animal and human populations.

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Avian Influenza Virus Prevalence in Migratory Waterfowl in the Central Flyway, 2007–2009

SCOTT R. GROEPPER, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE, USA
SCOTT E. HYGNSTROM, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE, USA
MARK P. VRTISKA, Nebraska Game and Parks Commission, Lincoln, NE, USA
THOMAS J. DELIBERTO, United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, Fort Collins, CO, USA

ABSTRACT Highly pathogenic avian influenza (HPAI H5N1) poses risks to wild birds, poultry, and humans. Personnel with the United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, state game agencies, and tribal cooperators collected >36,000 migratory birds from 2007–2009 to test for HPAI virus. Species from the dabbling duck, diving duck, and geese and swans functional groups were collected in all 10 states of the Central Flyway. Numerous combinations of the 16 hemaglutinin (H) and 9 neuraminidase (N) subtypes were discovered, but no HPAI H5N1 was found. The dabbling duck functional group had significantly higher ($p < 0.001$) prevalence of AIV than other functional groups and should be the focus of future surveillance.