

2008

North American Rabies Management Plan
A Partnership for Effective Management



Signature Page

North American Rabies Plan

The prevention and control of rabies in North America is a significant challenge. Rabies is an acute, fatal viral disease of mammals most often transmitted through the bite of a rabid animal resulting in impacts to public health, agriculture, and wildlife. Rabies costs governments and the people of North America hundreds of millions of dollars each year.

The North American Rabies Management Plan (NARMP) establishes a protocol for rabies management in North America by assessing and defining the needs, priorities, and strategies required to control and eventually eliminate terrestrial rabies and to determine methods for bat rabies management. Despite remarkable precedents and achievements in the rabies management field, greater accomplishments are possible through trilateral cooperation. The establishment of a NARMP represents a key step in facilitating a planning processes by which mutual border rabies control and prevention goals and objectives can be identified and better met among Canada, Mexico, and the United States. The plan is designed to provide direction and serve as a catalyst for collaborative rabies management actions at the continental level. Key components of this plan include routine communications on policies and rabies status, exchange of scientific and technical information, and collaboration on surveillance and control projects along the immediate borders of the three countries. The ultimate function of the plan is to provide a framework and forum for constructive interaction among the states and provinces and federal levels of Canada, Mexico, and the United States to address challenges jointly and, thus, better ensure that long-term rabies management goals are met within each country and in North America.

CANADA

Canadian Food Inspection Agency (CFIA) _____ Date

Public Health Agency of Canada (PHAC) _____ Date

MEXICO

Ministry of Environment and Natural Resources (SEMARNAT) _____ Date

Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) _____ Date
National Service for Health, Safety and Quality Food (SENASICA)

Ministry of Health (SALUD) _____ Date
National Center of Epidemiology Surveillance and Disease Control (CENAVECE)

THE NAVAJO NATION

The Navajo Nation _____ Date

UNITED STATES

Health and Human Services (HHS) _____ Date
Centers for Disease Control and Prevention (CDC)

United States Department of Agriculture (USDA) _____ Date
Animal and Plant Health Inspection Service (APHIS)

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I. Executive Summary

The prevention and control of rabies in North America is a significant challenge. Rabies is an acute, fatal viral disease of mammals most often transmitted through the bite of a rabid animal and impacts public health, agriculture, and wildlife. Rabies costs governments and the people of North America hundreds of millions of dollars each year for diagnosis, investigation of animal bites, treatment of humans who have come into contact with rabid animals, compensation for loss of livestock, quarantine, research, vaccination, maintenance of rabies laboratories, and animal control programs. In addition, each year tens of thousands of people are impacted by anxiety, fear, and trauma associated with potential or actual rabies exposure to themselves and their domestic animals. Despite implementation of aggressive rabies management strategies in many countries, rabies still results in 50,000 to 70,000 human deaths mostly in developing countries around the world. The number of human rabies deaths in North America has continued to decline as dog rabies has been brought under control and in some cases eliminated. Today, human cases in North America are often due to exposure to variants of wildlife rabies, underscoring the need for increasing emphasis on wildlife rabies surveillance and control. Moreover, effective wildlife rabies control is recognized as an integral component to break the cycle of canine rabies spillover into wildlife, particularly wild canids, a factor that could inhibit elimination of this key variant.

In North America, rabies persists in several terrestrial meso-carnivore species and bats. Specific variants of the rabies virus are adapted to species as well as specific geographic areas. The wildlife species most commonly confirmed with rabies include skunks (primarily *Mephitis mephitis*), raccoons (*Procyon lotor*), foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), coyotes (*Canis latrans*), and bats (*Chiroptera*). Also, rabies transmission by vampire bats (*Desmodus rotundus*) is an important public health and economic concern in Mexico and much of Latin America. Varying ecological, behavioral and biological attributes of diverse meso-carnivore and bat reservoir species introduce new challenges to contemporary rabies control programs that underscore the need for interdisciplinary collaboration among wildlife professionals, veterinarians, physicians, public affairs specialists, environmental compliance experts, economists, and others. Given the broad distribution of many of these reservoir species in North America, it follows that rabies impacts may occur locally, at the state level, regionally, nationally, or internationally.

Rabies vaccination of pets and livestock integrated with education programs and regulatory measures have led to greatly diminished numbers of rabies cases in domestic animals in the U.S., Canada, and Mexico. Successful programs to prevent rabies in humans and domestic animals have spotlighted the need for a more aggressive approach to manage rabies in wildlife reservoirs as an adjunct to traditional and innovative public health and agriculture initiatives. Wildlife rabies management goals in North America are shaped by low human rabies mortality and high social and financial costs associated with coexistence with specific rabies variants. Rabies management goals for wildlife are also dependent on the availability of safe and effective oral vaccines as well as economical bait-vaccine prices, the single highest cost in oral rabies vaccination (ORV) programs. Local, state, provincial or federal rabies management initiatives are being implemented in all three North American countries. Each country is moving

toward greater involvement of stakeholders, increased information sharing across borders, and is involved with research, planning, and direct actions for managing rabies. ORV has increasingly become an integral adjunct to conventional rabies prevention and control in Canada and the U.S. International cooperation, coordination, and collaboration among countries with common borders are essential for attaining the rabies management goals of containment and regional elimination of specific rabies virus variants. Cooperative rabies management through enhanced surveillance, coordinated ORV, use of natural and man-made barriers, and contingency actions is currently in place in several states and provinces in both the U.S. and Canada. Mexico has embarked on successful urban dog and cat rabies control within its states through mass vaccination campaigns, initiated enhanced rabies surveillance along the Mexican-U.S. border, and implemented vampire bat population control programs. Mexico embarked on an inaugural pilot ORV trial targeting difficult to vaccinate dogs in select towns and near landfills in 2008. In addition, several priorities have been identified for rabies management programs in Canada, U.S., and Mexico to succeed, all of which rely on effective and efficient coordination and collaboration. These priorities include: improved or new oral vaccines and baits to reach target species, optimized oral rabies vaccination strategies, effective communication, strategies to limit translocation and population growth, and access to sufficient long-term funding. To optimize the chance of achieving long range programmatic goals of eliminating specific variants of rabies virus in North American terrestrial carnivores, these key priorities must be addressed.

Despite remarkable precedents and achievements in the rabies management field, greater accomplishments are possible through trilateral cooperation. The establishment of a North American Rabies Management Plan (Plan) represents a key step in facilitating planning processes by which mutual border rabies control and prevention goals and objectives can be identified and better met among Canada, Mexico, and the U.S. Plan architecture has been formed and will continue to be shaped with input from each country through representatives in the fields of public health, agriculture and wildlife management. Rabies management creates the interface that requires integration of these areas of responsibility. This Plan establishes a protocol for rabies management in North America by assessing and defining the needs, priorities, and strategies required to control and eventually eliminate terrestrial rabies and to determine methods for managing bat rabies virus variants. The Plan is designed to provide direction and serve as a catalyst for cooperative rabies management actions at the continental level. Key components of this Plan include routine communications on policies and rabies status, exchange of scientific and technical information, and collaboration on surveillance and control projects along the immediate borders of the three countries. The North American Rabies Management Plan, therefore, is designed to foster international cooperation involving governments at all levels, indigenous groups, nongovernmental organizations, corporations, universities, and private citizens. Success of the Plan depends on effective partnerships among all segments of society that have a role in rabies management. This Plan can be easily modified to adapt to change as a function of planning processes among bordering states and provinces and at the federal level. The ultimate function of the plan is to provide a framework and forum for constructive interaction among the states and provinces and federal levels of Canada, Mexico, and the U.S. to address challenges jointly and, thus, better ensure that long-term rabies management goals are met within each country and in North America.

II. National Overviews



Canada

The Sub Issue Group: Canadian Rabies Committee was established to address prevention and management of all rabies variants from the perspectives of surveillance, assessment of risk, policy development, advice, public education, epidemiological studies and research, and outbreak preparedness, response and control. The committee includes members from provincial governments, the Public Health Agency of Canada, Canadian Food Inspection Agency, and Environment Canada.

In response, the Canadian Rabies Committee has developed a national plan for the management of rabies. Key topics addressed in the plan include disease surveillance and diagnosis, wildlife disease management strategies (planning, prevention, and control), management of human exposures, education and training, and communication.

- Surveillance of rabies variants should result in improved effectiveness of control measures, including a reduction in associated costs. Rabies surveillance should be supported by improved scientific methods and facilities. The plan describes the surveillance systems currently in place to monitor rabies activity in Canada, and how development of a comprehensive national rabies surveillance system can occur.
- Successful long-term wildlife disease management strategies are achieved through the development of an adaptive risk assessment and response framework. The various strategies for control include an element of advance planning which incorporates a cost benefit assessment for approaches to management. Prevention, control and eradication strategies include movement control, monitoring and control of population densities, and wildlife immunization methodologies. Also included is a component on the evaluation of response activities.
- Recommendations for the management of human exposures are provided by the National Advisory Committee on Immunization. The rabies management plan describes additional scientific research that is required in order to improve the overall management of human exposures. It also outlines a risk communications strategy, including approaches to improve public education on preventative measures.
- Education and training initiatives are identified that will improve disease prevention and management capabilities.
- Communication is essential to achieve the goals of the national plan, and to inform all sectors about issues related to the prevention and overall management of rabies in Canada. A coordinated multi-agency and multi-sector communication network is required.

To achieve the goals of the National Rabies Management Plan, the dedicated cooperation and participation of international, federal, provincial, territorial, regional, and local agencies, authorities, and institutions, as well as community organizations and the general public will also be required.

The topics, issues, and goals addressed in the national plan provide a framework for Canada's involvement in the North American Rabies Management Plan.

National Overviews



United States

Over the last 100 years, the primary rabies hosts and focus of rabies management have changed dramatically in the United States. Before 1960, the majority of rabies cases were reported in dogs. Through a combination of public education and pet vaccination programs rabies has been effectively controlled in companion animals. By the early 1960's, wildlife surpassed the dog in reported rabies cases. Today's principal rabies hosts are wild meso-carnivores and bats that have, for the past 15 years, accounted for 90% or greater of all rabies cases reported in animals in the U.S. and Puerto Rico (Blanton et al. 2006). Varying ecological, behavioral and biological attributes of diverse meso-carnivore and bat vectors introduce new challenges to contemporary rabies control programs that underscore the need for interdisciplinary collaboration among wildlife professionals, veterinarians, physicians, public affairs specialists, environmental compliance experts, economists, and others.

Low human mortality in the face of widespread wildlife rabies is a direct result of a comprehensive public health system in the U.S. that provides for rabies case investigations, education campaigns, timely and accurate laboratory diagnostic capability and effective post-exposure prophylaxis (PEP). The Centers for Disease Control and Prevention (CDC), state public health agencies and local health departments provide leadership in the U.S. for prevention, diagnostics and surveillance for rabies in humans and protecting public health. Modern day prophylaxis has proven nearly 100% successful in preventing mortality when administered promptly (CDC 2008a). Thus, in the U.S., human deaths associated with rabies occur in people who fail to seek timely medical assistance, usually because they were unaware of their exposure. Although human deaths are considered low in comparison to many other countries, trauma, anxiety, fear, and remorse are some of the emotional impacts experienced by those who have come into contact with potentially rabid wildlife, been treated for exposure to rabies, or who have had companion animals exposed to rabies. Increasing numbers of people will likely be impacted if rabies variants adapted to specific wild meso-carnivores is not prevented from spreading to areas not currently affected. The estimated public health costs associated with rabies detection, prevention, and control have risen, and are conservatively estimated to exceed \$300 million annually. Chief among these are the costs for vaccination of companion and other domestic animals, maintenance and operation of rabies laboratories, medical costs such as those incurred for exposure case investigations, PEP, and animal control programs (CDC 2008a). While the public health strategy is effective in preventing human deaths, the cost of coexistence with specific wildlife rabies variants is high and expected to increase unless specific wildlife rabies variants can be contained. Creating a rabies-free environment would not only bring mortality due to rabies to zero, but would also minimize the emotional impacts and costs associated with treatment.

Agencies such as state agriculture departments, local municipal animal control programs, and USDA, APHIS, Veterinary Services provide the critical leadership and necessary infrastructure to implement programs to protect domestic animals against rabies.

Rabies vaccination of pets and livestock integrated with education programs and regulatory measures have successfully reduced rabies in domestic animals in the United States. Successful programs to prevent rabies in humans and domestic animals have spotlighted the need for a more aggressive approach to manage rabies in wildlife reservoirs as a complement to traditional and innovative public health and agriculture initiatives. Wildlife rabies management goals for the U.S. are shaped by extremely low human rabies mortality and high social and financial costs associated with coexistence

with specific rabies variants. Rabies management goals for wildlife are also dependent on the availability of safe and effective oral vaccines as well as economical bait-vaccine price. Currently, Raboral V-RG® is the only vaccine approved for use in wildlife rabies control in the U.S. It is fully licensed for use in raccoons and coyotes and conditionally licensed for use in gray foxes. The same vaccine may be efficacious in dogs as they are also in the Canid family; however, there is currently no oral vaccine licensed for dogs. Research has shown that Raboral V-RG® is not highly immunogenic in skunks and mongooses. Thus, research on additional effective vaccines and palatable bait formulations is necessary to address rabies control specifically in these species or for species complexes (e.g., raccoon-striped skunk) where spillover may inhibit control.

A simple reduction in the incidence in specific variants of wildlife rabies is not likely a sound long-term national management goal, given the low human mortality rate and the high cost of oral rabies vaccination (ORV) (i.e., ORV would not lower the human mortality rate and rabies control costs would remain relatively high even if rabies incidence was reduced through ORV campaigns). Achieving lower incidence of wildlife rabies would not likely result in substantial long-term financial savings that may be expected with rabies strain containment and elimination. Thus, the strategic vision involves elimination of rabies in meso-carnivores in North America.

The current goals for terrestrial rabies management in the United States are:

1. Eliminate canine rabies in coyotes from south Texas; conduct surveillance and control programs to prevent reemergence of canine rabies in Texas.
2. Prevent the further spread of raccoon rabies in the eastern U.S. and gray fox in Texas.
3. Eliminate the raccoon and gray fox variants from some or all of their existing ranges in the U.S.
4. Collaborate in laboratory and field research that leads to the licensing of new oral vaccines, baits, and other methods that are safe, effective, and economical for use in all rabies reservoir species.
5. Develop rabies management strategies appropriate for skunks, mongooses, and feral or free-roaming dogs, as dogs may be a source of re-infection in wildlife reservoirs.
6. Explore and evaluate strategies for elimination of rabies in carnivores in the U.S.
7. Integrate U.S. rabies control plans with those in Canada and Mexico under a North American Rabies Management Plan for continental elimination of rabies in carnivores.

In addition to the rabies management goals for meso-carnivores, there is also an objective to collaborate in laboratory and field research where practical to explore the potential for use of vaccine or other tactics for containing and eliminating bat variants.

The effectiveness of ORV has been demonstrated in Europe, Canada, and the U.S. Intensive ORV baiting campaigns have resulted in the distribution of millions of baits annually in the U.S. (over 90 million to date) and Canada (Ontario, Quebec, New Brunswick and Newfoundland). These programs have shown effectiveness in containing and locally eliminating specific rabies variants in North America (Robinson et al. 2004, Linhart et al. 2002). Current wildlife rabies management programs in the U.S. delineate risk zones for the distribution of ORV based on the most current distribution of rabies cases and the expected direction of disease spread. Recently developed models serve as an additional tool to facilitate decision making (Russell et al. 2005). Vaccination zones are determined in cooperation with state rabies task forces, state health departments, or other state agencies with jurisdiction over vaccine use and application in wildlife and domestic animal species.

Operational oral rabies vaccination programs in the U.S. began in the early 1990s in New Jersey and Massachusetts to prevent the raccoon variant of rabies from reaching the highly populated vacation areas of Cape May and Cape Cod, respectively. Currently, ORV and enhanced surveillance programs are being conducted to combat the raccoon variant of the rabies virus in 24 eastern states and coyote and gray fox variants in Texas. Overall in 2007, coordinated ORV programs distributed nearly 12 million baits over 220,528 square kilometers. In addition, the program in South Texas to combat canine variant in coyotes eventually lead to the elimination of this variant in the United States in 2007. Wildlife Services has also conducted field tests for baits that could lead to ORV programs on skunks in several states, mongooses in Puerto Rico, and free-roaming/feral dogs on tribal lands in the southwest U.S. In 2005, the result of field bait testing in a “handout model” led to the first field trial using Raboral V-RG® in free roaming dogs on Navajo lands.

Since 1998, an annual national wildlife rabies management planning meeting has been coordinated and sponsored by the Wildlife Services, National Rabies Management Program (NRMP) that brings together more than 100 professionals from local, state and federal governments including health, agriculture and fish and wildlife departments as well as universities. The goals of this meeting are to: 1) provide advice and recommendations to the NRMP on strategic planning for wildlife rabies control; 2) exchange scientific and policy information on national rabies management issues; and 3) ensure interdisciplinary input to ORV decision making. These annual planning meetings have most recently been structured around 10 teams that focus on specific aspects of managing wildlife rabies in North America. The teams are made up of a diverse representation of agencies and organizations and are chaired by subject area experts. The teams include: Aviation Support, Communications Planning, Contingency Action Planning, Economic Analysis, NEPA Compliance, ORV Evaluation, Rabies Management Strategies, Research Prioritization, Surveillance/Laboratory Support and Vaccine/Bait/Biomarker. Typically teams conduct breakout sessions where focus area topics are discussed in order to make technical recommendations back to the larger group regarding wildlife rabies management and program operation. In 2007, the meeting format was changed slightly to allow for the implementation of a scoping exercise to gather detailed recommendations that will contribute to a comprehensive wildlife rabies management plan for the United States.

A draft national plan for the management of rabies in wildlife for the United States is being cooperatively produced by an interagency team with a target completion date of October 3, 2008. The national plan will be in the context of a 5-year time frame (2008-2012). The foundation of the national plan is based on the results of discussions at the March 27-29, 2007 annual NRMP meeting in San Antonio, Texas and prior planning efforts and documentation and existing foundation documents. A day of the meeting in 2007 was devoted to a strategic planning exercise that involved facilitated team discussions to provide recommendations on various components of the proposed plan.

The goals and objectives of the national plan are to:

1. Enhance coordination of wildlife rabies surveillance, management, research and communication among government agencies, universities and private organizations.
2. Prevent the spread of specific rabies virus variants in carnivores in the United States.
3. Eliminate specific rabies virus variants in carnivores.

National Overviews



Mexico

The management of rabies in Mexico is a priority for federal, state, and municipal governments and organizations concerned with livestock, wildlife, and the public health.

Ministry of Agriculture, Livestock, Rural Development, Fishing and Nutrition (SAGARPA), National Service of Agricultural and Food Health and Safety (SENASICA)

The occurrence of vampire bat (*Desmodus rotundus*)-transmitted rabies has expanded concurrent with the increase in the livestock industry. In terms of livestock, cattle remain most at risk for the virus; however swine, sheep, goats and horses are also susceptible. Establishing diagnostics, prevention, and control measures for rabies transmitted by vampire bats is necessary in order to decrease rabies incidence and minimize the threat to livestock.

SAGARPA reports that rabies transmitted by vampire bats has been found in 24 states. The vampire bat rabies-endemic states are located along the Pacific Ocean, from Sonora to Chiapas, and in the Gulf Coast region, from Tamaulipas south to the Yucatan Peninsula. These regions have a favorable climate and ecological conditions that allow for the presence of vampire bats. Vampire bats are the main rabies reservoir in these areas. From 2000 to 2006, vampire bat rabies was prevalent in 3.86% of cattle. Preventative measures have been taken in attempt to manage vampire bat populations, reduce the rabies focus and epizootic outbreaks, and stop the spread of this variant to new areas. Along with immunization of cattle, population control in bats is conducted using chemical products such as oral and systemic anticoagulants.

Mexico reported a total of 65.7 million livestock (31.5 million cattle, 8.9 million goats, 7.1 million sheep, 15.2 million swine, and 3.1 million horses) in 2006. Sixty-seven percent (44.1 million livestock) are located in the vampire bat rabies endemic areas according to the Animal Emergency and Health National System (DIVESA). Epidemiological studies conducted from 2000 to 2006 in Mexico, developed by SAGARPA'S zoo-sanitary campaign, provide information about rabies focus indicating a 3.86% rabies prevalence of vampire bat rabies in cattle. In the endemic areas, 527,085 cattle were at risk for acquiring rabies. Thus, the decrease in livestock production due to rabies deaths and other rabies-related issues represents an annual economic loss to the cattle industry of \$47.5 million USD. Paralytic rabies and the damage incurred from vampire bites in livestock increased zoo-sanitary risks and represented direct losses to the national livestock industry due to mortality, damaged meat, decreased milk production, devaluation of hides caused by bites, restrictions on commercialization and international export of suspect or sick animals, and decreased consumption of meat due to consumer fear of contamination by rabies.

From 2001 to 2006, a National Campaign "Alliances to the Country" against paralytic rabies in bovines had a primary goal of prevention and control of rabies in species with economic interest. The main methods used to accomplish this goal included education, training, immunization of livestock, and population reduction of vampire bats using anticoagulants. To

prevent and control rabies transmitted by vampire bats in the endemic area within the framework of decentralized resources, interagency-specific actions are required. However, the basic program strategies are the same:

1. Campaign promotion
2. Training at multiple levels and jurisdictions
3. Vaccination of susceptible livestock populations
4. Control of vampire bat populations
5. Updated diagnostic laboratories and implement new diagnostic techniques
6. Epidemiological surveillance in endemic areas and regions where rabies cases are reported in animals of economic importance at risk for vampire bat-transmitted rabies and other variants
7. Organization of specific interagency committees for collaboration and dissemination of information

The infrastructure for managing rabies diagnostics in endemic areas is managed at the local level by committees in each state. These committees, with a focus on promotion and protection of livestock, are responsible for assisting with zoo-sanitary measures around the country and for promoting disease research and livestock protection. Close coordination with neighboring countries will allow timely action to be taken during border rabies outbreaks, in addition to standardizing, modernizing, and updating scientific and technical methods.

As part of Mexico's commitment in epidemiological analysis of wildlife and domestic animal diseases, the Direction of Epidemiological Surveillance (DIVE) has developed a geographical-epidemiological zoo-sanitary information system that offers alternatives for the control and elimination of animal diseases in each state. This database system allows secure multi-user access at the state level to a database of rabies and other disease information that allows for integrated reporting, Geographical Information System analysis and mapping as well as epidemiological analysis. A primary goal of DIVE is to relay to users the importance of notification of rabies cases to authorities. Agreements developed during bi-national meetings have proposed that laboratories and other groups involved in preventing and eliminating rabies send timely and accurate warning notifications to DIVE regarding possible rabies outbreaks.

During the first stage of development, DIVE plans to integrate the national system reports with federal laboratories, such as the National Center of Diagnostic Services in Animal Health (CENASA), the National Center of Confirmation in Animal Health (CENAPA) and the Mexico-U.S. Commission for Foot and Mouth Disease and other Exotic Animal Diseases Prevention (CPA). During the second stage of development, regional laboratories such as Merida, Monterrey, and El Salto will be considered. Integration of the system to the remainder of the animal diagnostic health laboratories will be done during the third stage. This would result in total coverage of wildlife and domestic animal disease notification in Mexico, as well as increased efficiency in epidemiological analysis. To date, the DIVE system is still in its experimental stages, although we estimate that in a couple of months it will be running officially.

Ministry of Environment and Natural Resources (SEMARNAT)

The Ministry of Environment and Natural Resources (SEMARNAT) is the agency with primary responsibility for the conservation and management of wildlife populations in Mexico which are considered important to society and for maintaining biodiversity. However, the risk posed by wildlife diseases that impact both wildlife and human health deserves special attention within an ecological framework that promotes maintaining species viability while prioritizing the protection of human health and safety.

I. Health Concepts in Wildlife.

Diseases originate and change through evolution and ecological processes. Species that are most able to adapt to changing conditions are able to survive and reproduce. Due to the increased demand by humans for housing, food and other necessities, ecosystems are altered and resources may become scarce resulting in an increase in wildlife, domestic animals and human interactions. These interactions facilitate the spread of zoonotic diseases representing a high risk for society and must be taken into account by the animal and human health ministries.

Human activities such as timber harvesting and development reduce the boundaries between people and wildlife and disrupt ecosystem balance. In addition, these habitat changes may promote changes in disease vector populations and increase risks to wildlife, domestic animals and humans. Emergence of diseases in wildlife such as Avian Influenza, Rabies, West Nile Virus and others may have their origins in landscape level changes. Epizootic outbreaks of important diseases have economic, animal and public health impacts depending on the species involved. This situation is a motivating factor for further documentation and management of the risks that rabies represents through working with trained professional who can detect and respond to these kind of threats.

The general goals in wildlife health services were recently structured based on domestic animals and human health agencies experiences. Such agencies consider these issues important to economic and commercial development, protecting environmental welfare and promoting social development.

II. Inter-institutional Work Plan in Animal and Human Health.

Following the Mexican legislation in wildlife health, an interagency plan was established to implement actions to optimize available resources for health measures with the participation of Federal, State and local health agencies, with people interested on wildlife conservation, protection and management, livestock producers, and others. Initially this will be accomplished in part by:

- Monitoring wildlife rabies reservoir populations
- Characterization of isolates supported by CENASA and National Institute of Epidemiological Diagnostic and Reference (INDRE) from the Ministry of Health (SALUD)
- Integrating a policy of vaccination for wildlife species for conservation in areas of importance with the cooperation of SALUD and SAGARPA

These actions allow for the integration of sound rabies management and control strategies based on wildlife and rabies ecology.

Ministry of Health (SALUD)

During 2001-2006, the Ministry of Health (SALUD) conducted two different types of activities for controlling rabies: 1) managing transmission of the virus in dogs and cats; and 2) medical assistance to persons bitten by rabies suspect animals. The objective of these actions was to eliminate the risk of transmission of rabies to the human population.

Rabies cases in companion animals have decreased as a result of this program. Confirmed dog rabies declined from 177 reported cases in 2001 to 77 cases in 2006. There were four dog transmitted human rabies cases during this period and 19 other human rabies cases transmitted by wildlife (63% of which were transmitted by vampire bats).

A total of 651,000 people reported being harmed by companion animals at the onset of the program in 2001; 31% of which received treatment against rabies. A decrease was observed in 2006 as 620,100 people reported injury due to companion animals, 25% of which received treatment. The reduction in canine rabies cases is the result of a massive national campaign to vaccinate dogs involving 87.4 million doses of vaccine. As a result of the “National Week Against Rabies” mass vaccination campaign last year, 96.2 million doses were given, exceeding the goal by more than 10%. Dog population control, through a voluntary elimination (humane euthanasia) and sterilization (spay) program, involved 3 million animals for the period. During 2006, this effort increased by 3.3% as a result of municipal authorities participation. Regulation of dog over-population is an urgent need, but is being conducted in a humane manner.

The validation of animal rabies cases is accomplished through the participation of public health laboratories and coordinated by INDRE. Information in epidemiological surveillance and diagnostics can then be generated on a national scale for decision-making in disease control and development of national health programs. This information is also necessary for national biosecurity and biosafety and for use by laboratories from the Committees on Promotion and Livestock Protection (CFPP) coordinated by CENASA. This practice has increased from 16,500 samples submitted in the first year to 61,000 samples in the last year, a threefold increase. These studies are complemented through transfer of technology from the Centers for Disease Control and Prevention (CDC) through categorization of antigenic variant and from molecular studies of animal rabies of epidemiological interest.

The reduction in canine rabies cases is evident; however, the concentration of rabies cases in certain locations continues to be of concern. In addition, overpopulation of companion animals requires further review of procedures to determine if change is needed or if the same practices will achieve expected goals. Thus, additional strategies for prevention of rabies in companion animals are being considered for those areas. Furthermore, human rabies transmitted by wildlife represents a priority and challenge for agriculture and natural resources authorities.

III. Preface

Intentions for Preparing a Plan

Oral rabies vaccination has increasingly become an integral adjunct to conventional rabies prevention and control in Europe, Canada, and the U.S. International cooperation, coordination, and collaboration among countries with common borders are essential for attaining the rabies management goals of containment and regional elimination of specific rabies virus variants. Cooperative rabies management through enhanced surveillance, coordinated ORV, use of natural and man-made barriers, and contingency actions is currently in place in several states and provinces in both the U.S. and Canada (Slate et al. 2005). Mexico has embarked on successful urban dog and cat rabies control within its states through mass vaccination campaigns, is initiating enhanced rabies surveillance along the Mexican-U.S. border, has begun incorporating the use of monoclonal antigenic typing and genetic sequencing as recommended by the Centers for Disease Control and Prevention, and is considering pilot ORV trials targeting domestic and wild canids (Slate et al. 2005, SALUD 2006).

Establishment of a North American Rabies Management Plan (Plan) represents a key step in facilitating planning processes by which mutual goals and objectives can be identified and met among Canada, Mexico, and the U.S. Key components of this Plan include routine communications on policy and rabies status, exchange of scientific and technical information, and collaboration on surveillance and control projects along the immediate borders of the three countries. The planning process allows for critical input from diverse disciplines integral to achieving sound rabies management, such as policy makers, scientists, laboratory experts, and field biologists and technicians, which should lead to a robust plan with sound methodology for effectively managing rabies in North America. This Plan can be easily modified to adapt to change as a function of planning processes among bordering states and provinces and at the federal level (Slate et al. 2005).

The ultimate function of the plan is to provide a framework and forum for constructive interaction among the states and provinces and federal levels of Canada, Mexico, and the U.S. to address challenges jointly and, thus, better ensure that long-term rabies management goals are met within each country and in North America (Slate et al. 2005). The Plan is designed to provide direction and serve as a catalyst for cooperative rabies management actions at the continental level. As a result of increased information-sharing that should lead to access to the most contemporaneous rabies control methods and strategies, the Plan should promote cost efficiency in each country's national rabies management program. This document will serve as a guide for the Planning Team to work with stakeholders in cooperatively defining and coordinating mutually beneficial rabies management activities in North America.

Goals, Priorities, and Strategies

Local, state or provincial rabies management initiatives are being implemented in all three North American countries. However, the natural transborder movement of rabies reservoir species, potential for translocation, and possibility of spillover of rabies virus from domestic dogs into wildlife and visa versa, necessitates a more comprehensive understanding of the spatial-temporal distribution of rabies virus variants. An improved understanding of rabies spatial-temporal dynamics that should be forthcoming through new enhanced rabies surveillance and GIS mapping techniques is a prerequisite to the formulation of effective, long-term rabies management at the continental level.

All three countries are moving towards greater involvement of stakeholders, increased information sharing across borders, and have been involved with research, planning, and direct actions for managing rabies. Despite these remarkable precedents in the rabies management field, greater accomplishments are possible through trilateral cooperation. Through this Plan, mutually beneficial goals can be identified and priorities set for reaching these goals. Strategies can in turn be collaboratively formulated and implemented for the enhanced protection of humans, pets, domestic animals, and natural resources.

The crucial focus of the Planning Team's efforts will involve identifying and fostering opportunities for collaboration and cooperation to effectively manage rabies in North America. This Plan should be implemented in coordination with federal, state, provincial, local, and tribal governments engaged in managing rabies in North America.

The main goals, priorities, and strategies of the Plan are to:

- Strengthen working relationships among and within the three countries
- Promote cooperation among countries
- Facilitate communication and networking
- Increase stakeholder confidence in programs
- Broaden advocacy for effective programs
- Facilitate information sharing across North America
- Promote integrated monitoring and assessment to increase understanding of rabies and best methods for management and possibly elimination
- Encourage collaboration for mutually beneficial opportunities in research, surveillance, education, training, and transborder rabies management initiatives

Commitment to the Plan

The Plan's success is dependent upon the strength of partnerships involving federal, state, provincial, tribal, and local governments, businesses, conservation organizations, and individual citizens. Thus, to most effectively manage rabies in North America, the Planning Team and other team members and officials should, to the extent permissible under applicable law and to the extent that appropriated funds are available, agree to commit time and resources to set priorities and achieve goals.

Plan Architects: Team Membership and Chairs

The Planning Team is an international body that provides leadership and oversight for the activities undertaken in support of the North American Rabies Management Plan. Its purpose is to provide a forum to: 1) discuss major, long-term international rabies-related issues; 2) consider new scientific information and national and international policy developments; 3) identify appropriate methods for managing rabies across borders; 4) provide recommendations to policy makers regarding program and budget needs for accomplishing objectives; and 5) help formalize strategies for executing planned actions. The Planning Team is also responsible for updating the Plan and for determining the need to expand or diminish activities carried out through the planning process.

Planning Team Membership

The Team is composed of up to 10 members from each of the three countries including governmental (federal, state/provincial, and local) as well as non-governmental representatives selected by each country, and principally drawn from agencies, organizations, institutions, or experts dedicated to the management of rabies in North America:

- Canada
 - Canadian Food Inspection Agency
 - Public Health Agency of Canada
 - Provincial Health Department Representative
 - Provincial Natural Resources Department Representative
- Mexico
 - SAGARPA, SENASICA
 - SEMARNAT, General Direction of Wildlife (DGVS)
 - SALUD, National Center of Epidemiological Surveillance and Disease Control (CENAVECE)
 - State Authorities (State Offices of SAGARPA, SEMARNAT and SALUD)
 - Municipalities Department
- U.S.
 - U.S. Department of Agriculture (USDA)-Animal and Plant Health Inspection Service (APHIS)-Wildlife Services (WS)
 - USDA-APHIS-International Services (IS)
 - CDC
 - State Government Representatives (Wildlife, Agriculture, and Health)
 - University Research Representative
 - Tribal Liaison

During the past several years, interest in creating a North American rabies management strategy and developing coalitions has grown and, thus, planning meeting attendance has increased dramatically. In order for these meetings to continue to run smoothly, be effective, and allow for voting on significant country-level matters, the need to scale back the size of the meetings was determined. For meetings held in 2008 and beyond, each country will designate 5 members as voters and attendance will be limited to delegates from the above agencies.

Chair

The role of the chair will rotate among member countries every two years. The chair will be selected by consensus from and by the Team. With the support of the Planning Team, the chair will integrate the working agenda, call and convene meetings, promote all members attendance and effective participation, and communicate results to the Team.

Secretary

The secretary will be responsible for organizing meetings, taking minutes, and ensuring that the recommendations and advice—endorsed by the Planning Team—are incorporated in the Plan, the international rabies management program, projects, and annual budget.

Planning Team Roles and Procedures

Externally, the Plan operates within each country's laws and regulations, consistent with international treaties and agreements. Government wildlife, agriculture, and health officials have the authority and responsibility to ensure Plan actions are in compliance with applicable laws, regulations, and policies.

Internally, the Planning Team provides oversight for implementation of the Plan and dissemination of accomplishments. Scientific learning is documented and shared continentally by international conferences, peer-reviewed journal articles, scientific papers, technical presentations, reports, governmental agreements, and training programs. The Planning Team fosters cooperation and synergy through active leadership, lucid guidance, and meaningful assessments of rabies issues and activities conducted under the auspices of the Plan.

Role of Members

Members are expected to participate fully in the discussions and preparation of recommendations at all Team meetings. Members are strongly encouraged to attend all meetings; however, if members are unable to attend a scheduled meeting, they may send an alternate representative of equivalent authority in their place.

Meetings

The Planning Team will meet at least once (1) per year, subject to available funds. Meetings will be scheduled in conjunction with other meetings (e.g., National Rabies Management Team meeting sponsored by APHIS-WS or Rabies in the Americas [RITA] conference) to reduce costs and maximize participation of all committee members.

Languages

The three official languages of the Team are English, Spanish, and French. Interpretation and translation will be provided during formal meetings.

Decision-Making Procedures

The Planning Team shall strive for consensus in the development of recommendations on substantive issues. In cases where consensus cannot be reached, alternatives may be put forth for consideration by the Team.

Using Adaptive Management for Decision-Making

The Planning Team promotes the use of adaptive management, a broad concept allowing for the use of a diversity of approaches - planning, implementation, and evaluation - to improve management performance (Schubert et al. 1998). To manage adaptively, each program must have clear, quantifiable objectives; specific predicted biological outcomes of alternative management actions; monitoring procedures to measure outcomes; an evaluation process to compare outcomes with original objectives; and a commitment to use the lessons learned to adjust future decisions. The evaluation components may vary from simple monitoring of the results of routine management to rigorous experimental application of alternative management options (Schubert et al. 1998).

At regional, national, and international levels, the Plan can enhance cost-effectiveness by improving capacity in all three steps: planning, implementation, and evaluation. Planning, at all levels, is based on a set of assumptions, often embodied in implicit or explicit models. Strategic planning incorporates this biological foundation in selecting priority areas for specific management actions (Schubert et al. 1998). Strategic planning will also determine the distribution of Plan resources. Such models should be tested wherever the impact of the associated management decision is great and the uncertainty is significant. Because the Plan focuses continentally, nationally, regionally, and locally, adaptive management and strategic planning must also occur at multiple spatial scales. The spatial scale determines the relevant questions, challenges, learning opportunities, and the scope of possible inferences at each level (Schubert et al. 1998).

IV. Introduction

Background of Rabies in North America

Rabies is an acute, fatal viral disease of mammals most often transmitted through the bite of a rabid animal. The earliest records suggest rabies was present in dogs about 2300 B.C., but the disease probably evolved before recorded history (Blancou 2003). Despite its long coexistence with humans, rabies is a public and animal health problem that annually results in 50,000 to 70,000 deaths a year worldwide (WHO 1992).

The primary canine rabies epizootic that was predominant historically was brought under control through the combination of public education and vaccination programs for companion dogs in Canada and the U.S. in the middle of the 20th century. Canine rabies is presently being eliminated in urban dogs in Mexico as well. Massive pet vaccination campaigns, along with population reduction and animal birth control, have proven successful in a dramatically reduced number of reported cases of canine rabies in humans in Mexico (SALUD 2006). With the disappearance of canine rabies, however, wildlife rabies has become more apparent (Velasco-Villa et al. 2006). Mexico's achievement in controlling canine rabies must guide efforts to this new priority of managing rabies transmission by wild animals, primarily vampire bats, while continuing maintenance in prevention and control of canine rabies (SALUD 2006). The abundant and widely distributed rabies reservoirs among wild mammals complicate rabies control measures, including effective prevention of the virus in humans and many domestic animal species (Blanton et al. 2006).

Within most of the U.S. and Canada, terrestrial wildlife rabies reservoirs occur in geographically discrete regions where the virus transmission is primarily between members of the same species (Blanton et al. 2006). In Canada, the most significant vectors are red foxes (*Vulpes vulpes*) and striped skunks (*Mephitis mephitis*) (Bachmann et al. 1990). In the U.S., the major hosts are striped skunks throughout the Great Plains and in California, and raccoons (*Procyon lotor*) from the Atlantic coast to the Appalachian range (Blanton et al. 2006). In addition, the gray fox (*Urocyon cinereoargenteus*) is host to two known unique rabies virus variants--one in west-central Texas, the other in Arizona. During the mid-1980's through 2000, canine rabies from dogs had infected the coyote (*Canis latrans*) in south Texas. Through coordinated ORV, canine rabies has been eliminated from the U.S. (TDSHS 2007, Slate et al. 2005). In Mexico, several species of skunks (*Spilogale* sp.) are becoming recognized as rabies vectors (WHO 2005). All of these terrestrial wildlife species are maintaining one or several distinct variants of the rabies virus in North America (Blanton et al. 2006, Nadin-Davis et al. 2001, Velasco-Villa et al. 2006).

Rabies has also been detected in bats (*Chiroptera*) across North America. The *Chiroptera* have life history traits that are distinct from terrestrial carnivores. They are small, long lived, have low intrinsic population growth rates and different bat species occupy a variety of well-defined ecological niches (Calisher et al. 2006). The properties of lyssaviruses adapted to bats are likely different from those causing *Carnivora* rabies, although the population biology and epidemiology of bat rabies have not been sufficiently explored (Kuzmin et al 2006, Botvinkin et al. 2003). Several variants occur in a single bat species, and the geographical distribution of variants is overlapping. Spillover to terrestrial animals is observed frequently (Velasco-Villa et al. 2006).

Though the incidence of human rabies is relatively low in temperate North America, approximately half of the cases are caused by infections with bat rabies viruses, most frequently with a virus that is associated with silver-haired bats (*Lasiurus noctivagans*) and eastern pipistrelle bats (*Pipistrellus subflavus*) (Franka et al. 2006, Hanlon et al. 1999b). Vampire bat rabies is a major public health problem in subtropical and tropical areas of the Americas such as Mexico. A genotype 1 virus related to the other American bat viruses is maintained in haematophagous bats (mainly *Desmodus rotundus*). This virus is frequently transmitted to domestic animals and humans (Velasco-villa et al. 2006). Vampire bat-transmitted bovine paralytic rabies has a significant economic impact on livestock industries (Mayen 2003, Arellano-Sota 1993). To combat this problem, Mexico continues to evaluate the necessary technology for controlling rabies in vampire bats. Currently, efforts are focused on prevention and control of rabies through vaccination of susceptible livestock populations and reduction of vampire bat populations in the endemic area.

Persistence of multiple variants of rabies virus in wild *Chiroptera* and *Carnivora* presents a continuing challenge to medical, veterinary, and wildlife management professionals. ORV targeting specific *Carnivora* species has emerged as an integral adjunct to conventional rabies control strategies to protect humans and domestic animals. ORV has been applied with progress toward eliminating rabies in red foxes in Western Europe and Southern Ontario, Canada. Since 1995, coordinated ORV has been implemented among eastern states in the U.S. to prevent the spread of raccoon rabies and to contain and eliminate variants of rabies virus in gray foxes and coyotes in Texas (Slate et al. 2005). With the shift in reported rabies cases from domestic animals to wildlife, Mexico is also considering embarking on an ORV program in domestic and wild *Carnivora* to augment its pet vaccination and animal birth control campaigns.

Reported Rabies Cases in Canada from 1996-2005 (PAHO 2007)										
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Humans	0	0	0	0	1	0	0	1	0	0
Dogs	14	9	11	10	24	16	8	4	7	12
Cattle	35	13	29	39	36	22	12	10	15	16
Cats	6	5	8	4	8	4	9	5	2	4
Other										
Domestic	0	0	0	7	10	12	6	8	9	2
Bats	0	0	0	42	72	103	112	115	83	94
Other										
Wildlife	233	108	321	440	587	387	308	237	221	214
Total	288	135	369	542	738	544	455	380	337	342

Reported Rabies Cases in the U.S. from 1996-2005 (PAHO 2007)										
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Humans	4	4	1	0	5	1	3	2	8	1
Dogs	111	126	113	100	99	76	85	108	94	76
Cattle	131	122	116	135	82	80	115	98	115	93
Cats	266	300	282	277	248	264	298	321	281	269
Other										
Domestic	0	0	0	73	58	49	73	0	43	55
Bats	0	0	0	989	1240	1281	1373	1212	1361	1408
Other										
Wildlife	6554	7899	7324	6407	6796	6869	7309	6556	6292	5923
Total	7066	8451	7836	7981	8528	8620	9256	8297	8194	7825

Reported Rabies Cases in Mexico from 1996-2005 (PAHO 2007)										
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Humans	22	23	15	9	4	7	3	1	0	8
Dogs	852	521	394	317	244	117	105	75	36	125
Cattle	1535	39	395	108	271	148	154	275	303	479
Cats	0	16	29	18	6	0	6	13	4	4
Other										
Domestic	0	0	0	22	21	19	4	28	26	33
Bats	0	0	0	9	5	4	7	6	3	12
Other										
Wildlife	0	12	32	21	18	24	21	27	17	45
Total	2409	611	865	504	569	319	300	425	389	706

Public Health Importance of Rabies

The number of human rabies deaths in North America has continued to decline with the elimination of dog rabies. In the U.S., human cases have declined from more than 100 annually at the turn of the 20th century to an average of one or two people per year by the 21st century (CDC 2006). With the elimination of dog rabies, the majority of human cases in the U.S. and Canada have involved wildlife variants of rabies virus. In Mexico, human rabies has been substantially reduced from a total of 241 cases during the 1990s to less than 10 per year in the current decade (PAHO 2005). While dog rabies has been eliminated in developed and some developing countries in the Americas, the health problem continues with respect to bat transmission and terrestrial wildlife reservoirs (Velasco-Villa et al. 2002, 2006). Thus, the illness remains a public health concern in both developed and developing countries. The diversity of rabies reservoirs in wildlife makes prevention and control quite complex (Velasco-Villa et al. 2002).

Rabies costs governments and the people of North America hundreds of millions of dollars each year for diagnosis, investigation of animal bites, treatment of humans who have come into contact with rabid animals, compensation for loss of livestock, quarantine, research, vaccination, maintenance of rabies laboratories, and animal control programs. In addition, each year tens of thousands of people are impacted by anxiety, fear, and trauma associated with potential or actual rabies exposure to themselves and their domestic animals (Public Health Agency of Canada 2005, Slate et al. 2002, Rupprecht et al. 1995).

One of the highest financial expenditures in any country is the cost of rabies PEP. The type of vaccine, vaccine regimen, and route of administration, as well as the type of immunoglobulin used, all significantly influence the cost of PEP (WHO 2005). For instance, a single course of PEP in the U.S. costs between \$1600 and \$2800 USD (Public Health Agency of Canada 2005) which equates to \$1866-\$3265 CAD and \$17,897-\$31,322 MXN (OANDA 2007) with revised recent estimates averaging as high as \$3400 USD (Shwiff et al. 2007) (equal to \$3965 CAD and \$38,005 MXN [OANDA 2007]). As many as 16,000 to 39,000 people receive PEP in the U.S. every year (Finnegan et al. 2002) and approximately 1,000 and 1,500 people in Canada receive PEP each year (Public Health Agency of Canada 2005). In Mexico, approximately 90,000 people are bitten by dogs each year with PEP given to approximately 34% of them (Garza 1997). In addition to the expense of rabies biologicals are expenditures for the physician, hospital, the loss of income as a result of the need to physically visit a clinic, and the emotional and psychological impact of PEP (WHO 2005).

Modern day prophylaxis has proven nearly 100% successful in preventing mortality when administered promptly. In North America, human fatalities associated with rabies occur in people who fail to seek timely medical assistance, usually because they were unaware of their exposure to rabies (CDC 2006). Even as rabies deaths have declined, the public health costs of rabies detection, prevention, and control have steadily risen, exceeding \$300 million annually in the U.S. (MedicineNet.com 2002). The public health cost to save one human life from rabies ranges from \$10,000 to \$100 million USD, depending on the nature of the exposure and the probability of rabies in a given region (MedicineNet.com 2002).

Impacts to Agriculture and Wildlife

Rabies is not, in the natural sense, a disease of humans. Human infection is incidental to the reservoir of disease in wild and domestic animals; therefore, a more accurate projection of the impact of rabies on public health should include an estimate of the extent to which the animal population is affected and the expense involved in preventing transmission of rabies from animals to humans (CDC 2006).

Agricultural Impacts

Rabies in livestock, especially cattle, is often reported in North America, but annual economic losses within the three countries are not clear. However, due to the large numbers of livestock (i.e., cattle, swine, goats, and sheep) in North America, the threat of rabies spread is real and represents a challenge to the livestock industry. In addition to the possibility for livestock losses due to rabies exposure in unvaccinated animals, costs can include potential quarantining of the remaining exposed herd (MacInnes and LeBer 2000). In Canada for example, herds are quarantined for 60 days following the death of a cow due to rabies. Quarantine restrictions often cause a domino effect as shipments off property are put on hold, cash flow is interrupted, additional feed is consumed, and animals held too long may fatten too much, resulting in lower prices when sold (MacInnes and LeBer 2000).

Rabies transmission by vampire bats is an important public health and economic concern in Latin America (PAHO 1995). The principal vector of sylvatic (wildlife transmitted) rabies in Latin America is *Desmodus rotundus*, a hematophagous bat found from Mexico to northeastern Argentina (PAHO 1995, De Mattos et al. 1999). Estimates on the Mexican livestock industry indicate losses of more than \$46.7 million USD per year from vampire bat-transmitted rabies in terms of mortality, damaged meat, decreased milk production, devaluation of hides caused by bites, restrictions on commercialization of suspect or sick animals, and decreased consumption of meat due to consumer fear of contamination by rabies (PAHO 1995; Jimenez 2004, 2007; Shwiff et al. 2006).

- According to Statistics Canada (2006), livestock in Canada totals approximately 29.87 million head (14.8 million cattle, 14.46 million swine, and 614,200 sheep).
 - More than eight million of these animals are located in Ontario (Statistics Canada 2006), a province that has recently experienced the spread of raccoon strain rabies northward from the U.S.
- The USDA National Agriculture Statistics Service (NASS 2006) lists livestock totals in the U.S. at 166.3 million head (97.1 million cattle, 60.1 million swine, 6.23 million sheep, and 2.83 million goats).
 - The state of Texas, currently managing both coyote and gray fox rabies, is the largest cattle producing state in the U.S., with more than 14 million head, and contributes more than \$15 billion to the state's economy (Texas Comptroller of Public Accounts 2003).
- SAGARPA-SENASICA reported the livestock industry in Mexico at approximately 65.7 million head in 2006 (31.5 million cattle, 8.9 million goats, 7.1 million sheep, 15.2 million swine, and 3.1 million horses).
 - Within the vampire bat rabies endemic area, 44.1 million livestock (13.6 million cattle, 7.6 million goats, 6.4 million sheep, and 13.7 million swine, and 2.7 million horses) are at risk (SIAP 2007).

In some regions within Mexico and other Latin American countries, urban (mainly canine) and sylvatic rabies transmission cycles overlap, complicating the understanding of rabies epidemiology and control of the disease. The simultaneous presence of more than one reservoir and more than one rabies virus variant makes identification of the actual source of infection critical. The scant information on rabies diagnosis in wild reservoir species severely hampers identification in the regions affected (Velasco-Villa et al. 2002, Velasco-Villa et al. 2006, De Mattos et al. 1999).

Wildlife Impacts

Infectious disease is an increasing threat to many of the world's rare and endangered wild vertebrates (Laurenson et al. 2005, Randall et al. 2004). Analysis of disease outbreaks suggests that carnivores appear to be particularly susceptible. The susceptibility of wild canids may arise from a variety of intrinsic social and ecologic factors, but is undoubtedly also due to their susceptibility to general pathogens in the most abundant carnivore, the domestic dog (Randall et al. 2004). Rabies has emerged as the most common cause of disease outbreaks in wild canids, causing severe population declines and local extirpations in a range of carnivorous species (i.e., black-footed ferrets, gray wolves, Channel Island foxes, Ethiopian wolves, African wild dogs, and lions) (Laurenson et al. 2005, Randall et al. 2004).

Rabies virus is a generalist pathogen in nature as it has the ability to infect a wide range of species. Epidemiologic theory predicts that pathogens that cause major host mortality or reduce fertility are unlikely to be able to persist in small populations. These generalist pathogens must, therefore, persist in another reservoir population from which they can spill over and cause a single epidemic or repeated epidemics in an endangered population (Laurenson et al. 2005). The reservoir of infection is often the domestic dog (mainly in developing countries), but wild reservoirs have also been implicated. For example, red foxes in Europe, yellow mongooses in South Africa, and raccoons, gray foxes, and skunks in North America are all considered wild reservoirs for rabies.

A rabies outbreak in the world's rarest canid, the endangered Ethiopian wolf (*Canis simensis*), is the most current example of severe population decline leading toward local extirpation of an endangered species (Randall et al. 2004). The Ethiopian wolf is found in only seven Afroalpine highlands in Ethiopia. With up to 300 of the global estimate of 500 wolves, the Bale Mountains in south-central Ethiopia are home to the largest and most important population of this species. Overall, the Bale Mountains wolf population was estimated to have declined from approximately 450 to 120-160 animals in the early 1990s as the result of a rabies outbreak. A second outbreak, from 2003-2004, likely killed 74 of a pack of 95 wolves (not all dead wolves were tested for rabies and some wolves that disappeared were not recovered). All available evidence suggests that domestic dogs are the reservoir for rabies both in the Bale Mountains and Ethiopia. The genetic analysis identified the virus to be of canid type and no wildlife reservoir has ever been identified in this country (Randall et al. 2004).

Rabies is endemic in Ethiopia and remains both a public health and economic problem through livestock losses in these impoverished rural communities. More than 32 domestic dogs and 20 cattle exhibiting clinical signs consistent with rabies were reported in communities adjacent to the Bale Mountains National Park in the same period, and at least three people were bitten by suspected rabid dogs (Randall et al. 2004).

The Ethiopian Wildlife Conservation Program (EWCP) has been working in the Bale Mountains since 1995 for the conservation of the Ethiopian wolf. The EWCP works with local communities and the Ethiopian government to implement a suite of activities including education, disease prevention (through vaccination of domestic dogs), hybridization prevention (through domestic dog sterilization), strengthening protected areas, training and capacity building of Ethiopian institutions, promoting tourism, monitoring, and research. More than 70% of domestic dogs in core wolf areas within the national park have been vaccinated against rabies, and, where resources have allowed, the dog vaccination campaign has been extended to surrounding communities. The EWCP also implemented a trial intervention, which aimed to contain the disease within the area of the initial outbreak. Since oral rabies vaccines are not currently licensed for use in Ethiopia, parenteral vaccination was the only means to directly protect wolves. The wolf trap-vaccinate-release campaign began in 2003 in packs adjacent to those already affected. The subsample of wolves recaptured 30 days post-vaccination showed 100% seroconversion (Randall et al. 2004).

This outbreak has highlighted that rabies is a continued threat to endangered canids and that conservationists are often ill-equipped to manage infectious disease. First, lack of information often hinders management. In addition, although a variety of theoretic approaches to disease management exist, relatively few may be feasible or effective. Finally, considerable funds are required to effectively prevent and control disease threats. Nevertheless, results obtained from this trial intervention will be invaluable in assessing the effectiveness of vaccination against rabies in Ethiopian wolves and of the approach in general (Randall et al. 2004).

The Ethiopian wolf example underscores the importance of managing rabies in North America to enhance protection of our endangered, threatened, and rare wild vertebrates.



Need for Coordinated Rabies Management in North America

In North America, rabies persists in several terrestrial carnivore species and bats. Specific variants of the rabies virus are adapted to species as well as specific geographic areas within the same species (e.g., unique variants occur in three distinct geographic areas in the striped skunk) which act as reservoirs for the rabies virus. In addition, spillover may occur from reservoir species to other wildlife species (e.g., woodchuck infected with raccoon variant of the rabies virus). These other species can then serve as a vector for virus transmission, although the virus does not become established within these species (e.g., woodchucks are not considered a reservoir for the rabies virus). Given the broad distribution of many of these reservoir species in North America, it follows that rabies impacts may occur locally, at the state level, regionally, nationally, or internationally.

To effectively address public and animal health impacts at each of these geographic scales typically requires the application of several steps and methods in an integrated fashion. The simplest, local scenario of a potential human exposure to wildlife rabies requires consideration of integrating methods ranging from exclusion to removal of the suspect animal (Slate 2005). Additional key components of the integrated strategy include determining if access to the suspect animal is possible for laboratory rabies diagnosis. Adherence to formal contact protocols with animal or public health officials to ensure that appropriate medical or veterinary steps are taken in a timely manner is critical as well. At the regional, national, or international level, containment and elimination of terrestrial rabies in wildlife is a much more daunting, multifaceted task, requiring the integration of enhanced rabies surveillance, oral rabies vaccination, a range of contingency support approaches, effective post-vaccination evaluation procedures, economic and ecologic decision indicators, and other factors into a comprehensive rabies management strategy. To achieve success, expertise from several disciplines including wildlife management, veterinary and human medicine, economics, and others must be brought together in order to solve such complex, integrated programs of scale (Slate 2005).

Visions/Objectives/Goals

The purpose of the Plan is to effectively manage rabies in North America through partnerships that are guided by sound science. This Plan establishes a protocol for rabies management in North America by assessing and defining the needs, priorities, and strategies required to control and eventually eliminate terrestrial rabies and to determine methods for managing bat rabies virus variants.

Laboratory Diagnostic Capability and Support

Laboratory-based surveillance is an integral part of any rabies management plan. The direct fluorescent antibody (DFA) test is the current standard in most industrialized countries for rabies diagnosis (WHO 2005). Each country is encouraged to define a national protocol and methods to maintain diagnostic expertise and continuing education. In addition to the DFA test, laboratories should maintain the ability to characterize rabies virus variants by monoclonal antigenic typing and genetic sequencing (Blanton et al. 2006, Velasco-Villa et al. 2006, Hanlon et al. 1999b).

The introduction to DFA protocol in the U.S. is presented below. The protocol, in its entirety, can be obtained from the CDC website

(http://www.cdc.gov/ncidod/dvrd/rabies/professional/publications/DFA_diagnosis/DFA_protocol-b.htm)

and is entitled:

“Protocol for Postmortem Diagnosis of Rabies in Animals by Direct Fluorescent Antibody Testing: A Minimum Standard for Rabies Diagnosis in the United States.”

Introduction (from CDC 2007b):

Among the findings of the National Working Group on Rabies Prevention and Control in 1999 was the need for a minimum national standard for the laboratory diagnosis of rabies (Hanlon et al. 1999b). In response to this recommendation, a diagnostic committee was formed from representatives of national and state public health laboratories to evaluate procedures employed by rabies diagnostic laboratories in the U.S. The National Working Group and the diagnostic committee’s stated goal is to improve the overall quality of rabies testing through the formulation of guidelines and standards for equipment, reagents, training, laboratory protocols, quality assurance, and laboratory policy for rabies diagnosis.

As an initial step, the diagnostic committee prepared a standardized protocol for the analytical phase of rabies testing using the DFA test and evaluated the protocol by comparison testing of 435 samples submitted to public health laboratories for rabies diagnosis. Later documents will address other elements that can affect the quality of laboratory testing such as the pre-analytical steps (rationale for specimen submission), the post-analytical phase (result reporting and confirmatory testing), laboratory policy, and quality assurance.

The standardized protocol was developed from published procedures and the collective laboratory experience of the diagnostic committee members. The committee recognizes that a range of possible methods may achieve the desired outcome for some of the less critical steps in the diagnosis of rabies and that laboratory policy may be regionally defined in some cases; however, the goal of the diagnostic committee was to establish a single protocol by which all other methods could be validated by comparison. This method should be followed carefully as modifications or short cuts in procedures often lead to false positive and false negative results and non-specific or uninterpretable reactions.

The standard protocol for DFA will be made available to each rabies testing laboratory by postal or electronic mail and by participation in a training workshop. In addition, the protocol and other documents will be placed on the websites maintained by the CDC at www.cdc.gov/ncidod/dvrd/rabies and the Association of Public Health Laboratories (APHL) at www.aphl.org. A listserv is planned so that an interactive dialogue may be established to address questions and disseminate information about rabies testing.

In addition to the procedural aspects, each testing laboratory must maintain the competency of its employees. All new employees should be trained in all aspects of the procedure and competency should be evaluated by the senior technologist on a routine basis. Competency can be assessed by observation of all procedural aspects on a routine basis, as well as performance on proficiency test samples, and testing on internal blind samples. All training should be documented throughout the training period, and observations of breakdown in technique or procedures should be noted and corrected before the lead technologist can be assured that the trainee can perform the procedure in a competent and reliable manner. All laboratories performing this DFA test for rabies should participate in national rabies virus proficiency testing, available through the Wisconsin State Laboratory of Hygiene. Enrollment information may be obtained through their web site (www.slh.wisc.edu/pt) or by calling 1-800-462-5261.

At least once every 6 years, each laboratory should send a representative to the National Laboratory Training Network sponsored course “Laboratory Methods for Detecting Rabies Virus.” The course details all aspects of rabies testing and provides an opportunity for diagnosticians to meet colleagues from other states and discuss common problems and their solutions. Advances in rabies diagnosis and research are presented at the Rabies in the Americas meeting, held every year at a location in North, Central, or South America.

Bench training and consultation on basic aspects of rabies diagnosis are available at the state public health laboratories in New York, California, Texas, Wisconsin, and Ohio and at the national rabies laboratory at CDC. These laboratories can be contacted at any time with questions or requests for consultation and training. Laboratories that annually process less than 100 samples may have particular difficulty maintaining rabies diagnostic proficiency and may want to work closely with larger laboratories where additional resources are available. Sources of funding are being investigated for those states that have no travel budget to attend meetings, workshops, or seminars. Potential sources that are being explored include APHL, the American Society for Microbiology (ASM), or the Epidemiology and Laboratory Capacity (ELC) program at CDC.

Methods

Managing rabies in North America is complex. There may be multiple vectors within a specific area. Thus, the most effective approach is often one that integrates tactics in a coordinated strategy. Tactics may include: reduction of vector populations, modification of habitats, parenteral (injectable) vaccination through Trap-Vaccinate-Release (TVR) programs, oral vaccination, and enhanced rabies surveillance to complement public health surveillance (Hanlon et al. 1999a).

The utility of rabies management methods, either independently or in an integrated control program, will depend in large part on the overall objectives (Hanlon et al. 1999a). Objectives for the control of rabies may vary locally, regionally, nationally, or continentally. State and provincial wildlife agencies with the statutory authority to manage wild animals may not universally endorse the same management strategy as their respective state/provincial public health agencies (Hanlon et al. 1999a). Moreover, federal governments may not agree on the necessity, immediacy, or measures to be used for managing rabies along national borders.

Methods for Controlling Rabies in Wildlife

Population reduction

Rabies transmission within animal populations is density dependent or at least density related. Thus, population reduction techniques have been employed in the past in an attempt to reduce susceptible animals below the threshold necessary for rabies to spread through populations. The program to control skunks infected with rabies in Alberta, Canada, is one example of this method (Rosatte et al. 1986, Pybus 1988). Bounty incentives, regulated hunting and trapping, ingestible poisons, and fumigation of dens have all been employed to control populations with varying levels of success. MacInnes (1998) reviewed some of the past efforts to control rabies with population reduction of reservoir species and concluded that, with few exceptions, most such efforts have failed.

The estimated costs of population reduction vary widely; however, such efforts would most likely be cost prohibitive if programs relied on labor-intensive trapping and shooting. Other issues, such as impacts to nontarget species, limited public support for population reduction efforts, and the impracticality of obtaining approval from the many hundreds of thousands of landowners on whose properties the lethal control methods would have to be conducted, clearly restrict the feasibility of this approach as a single tactic for broad-scale control of rabies (Hanlon et al. 1999a). Presently, population reduction is most likely to be publicly accepted and effective in localized or site-specific scenarios (e.g., reducing the density of raccoon populations in parks where visitors may come in contact with potentially rabid animals). Population reduction also may continue to merit consideration for species or situations in which all other methods are not practical (Hanlon et al. 1999a, Rupprecht et al 2006).

Studies on the effect of reservoir species population reduction to control rabies show that there are very few examples where such methods alone have either eliminated the disease or have prevented its spread to previously uninfected areas (MacInnes 1998). The resilience and high reproductive potential of most rabies vector carnivores and the capacity of the environment to provide food, water and shelter, most often render population control efforts futile. Thus, a more promising approach involves a combination of population reduction and immunization, as has been successfully applied in Canada in 1999 to stop the northward advance of the raccoon rabies epizootic (Rosatte et al. 2001).

Habitat Modification

Habitat modification is a useful site-specific management approach that can reduce the chance of interaction between humans and potential vectors like skunks, raccoons, and bats. Managing refuse through routine garbage pickup, using animal-proof garbage receptacles, making pet food inaccessible to wild animals, capping chimneys, and screening louver vents are examples of habitat modification to minimize contact between wild animals, pets, and people (Hanlon et al. 1999a).



Monitoring and Surveillance

Monitoring and surveillance activities (e.g., capture and release, lethal removal, collection of roadkills, use of nuisance wildlife captured during other management activities) of targeted animal species are used to determine prevalence of rabies in wildlife populations. Monitoring and surveillance are integral to all efforts of rabies control and should be pursued more aggressively and with an analytic design during rabies control field trials to objectively evaluate effectiveness (Hanlon et al. 1999a). National typing of rabies virus variants is critical for a better understanding of the spatial and temporal distribution of different variants. Such information is essential in view of the differences in behavior and population dynamics and structure among the major wildlife vectors. If regional rabies management efforts directed at specific variants of the virus are initiated, historic and current surveillance data on variants are also needed. Basic passive surveillance often employed for public health protection is insufficient for monitoring the effect of oral vaccination on rabies in wildlife (Hanlon et al. 1999a).



Education campaigns

Campaigns by federal, state, provincial, tribal, and local health departments and others already occur in North America in conjunction with rabies control programs to educate the general public about rabies prevention and risks. Reducing the interaction between humans and potentially rabid animals involves educating the public on avoiding direct contact with wildlife and that any person bitten by a wild animal, including bats, must seek medical attention (CDC 2008a). It also involves educating the public on exclusion and habitat modification techniques (e.g., suppression of food sources through garbage management, elimination of potential shelter in and around human habitation) that would help limit wildlife access to essential resources (Hanlon et al. 1999a). Educating the public on the negatives of relocation/translocation of wildlife is also important for minimizing the spread of disease (Hanlon et al. 1999a). Furthermore, education campaigns should discuss responsible pet ownership, the need for routine veterinary care, the critical importance of ensuring that pets receive regular rabies vaccination (CDC 2008a), and the dangers in maintaining feral dog and cat colonies, especially in rabies endemic areas.

Trap-Vaccinate-Release (TVR)

TVR has been used in certain localized areas for reducing the incidence and spread of rabies in raccoons and skunks (Brown and Rupprecht 1990; Rosatte et al. 1990, 1992, 1993). This method has not been attempted for vaccination of foxes and coyotes as they are much more difficult to capture in cage traps (Baker and Timm 1998) and the use of other devices such as leghold traps and snares has shown to be problematic in capturing and releasing a large enough population (Rosatte et al. 1993). TVR is best applied as a single control tactic at a local site specific level or as an integrated approach in larger ORV efforts.

TVR programs generally result in a higher percentage of a target population being vaccinated than ORV, although it takes much longer to accomplish in a given area. TVR, however, is only logistically feasible in areas of about 1500 km² or smaller due to labor, time, and equipment requirements to trap areas of that size. For example, in Ontario, seven trappers working from July to October were required to trap and vaccinate 50-85% of raccoons in an area less than 700 km², whereas the same area could have been treated with aerially distributed ORV baits in half a day (Rosatte et al. 2001).

The basic concept of TVR is that population (herd) immunity is created by vaccinating a major portion of a susceptible reservoir population, thus blocking transmission among reservoir members in a rabies-endemic area. In other words, the proportion of immune-to-susceptible animals is so great that the rabid animal has a greatly reduced probability of contacting susceptible animals. Since no parenteral rabies vaccine has been licensed for wildlife, injectable rabies vaccines destined for use in domestic animals are employed on an experimental basis. Capturing and vaccinating wild animals with parenteral rabies vaccines is costly and labor-intensive. Thus, TVR is most practically applied on a smaller-scale for site-specific emergency responses, preferably in combination with rabies vector population reduction (Merial Limited 2005).

TVR programs have been employed in localized areas with success in Canada and the U.S. For instance, a TVR program was tested in Toronto in 1984 in an effort to control skunk rabies before an oral rabies vaccine had been developed. The program cost approximately \$450-\$1150 CAD per km² (\$387-\$988 USD/km² or \$4,307-\$11,004 MXN/km² [OANDA 2007]) in 1984 or approximately \$877-\$2240 CAD in today's market (U.S. Department of Labor 2007). However, some of the costs were offset by fewer people needing PEP (Finnegan et al. 2002).

In 2001, a rabies epizootic in Flagstaff, Arizona occurred that was most likely spillover of a big brown bat (*Eptesicus fuscus*) rabies variant into striped skunks where it began to spread as a result of skunk to skunk transmission (Leslie et al. 2006, Weissinger et al. 2005, Engeman et al. 2003, USDA 2005). Twenty-three percent of rabies cases occur in skunks in the U.S. (Blanton et al. 2006), with several variants often reported in skunks (e.g., skunk, raccoon, gray fox, and bat). Prior to 2001, rabies spillover had not been documented in skunks in Arizona. Because no oral rabies vaccine or bait is currently registered for use on skunks in the U.S., a 6-week TVR project was conducted in the suburban striped skunk population in the Flagstaff area. From 2001 through August 2004, no skunks tested positive for bat rabies, clearly a reduction in cases and suggestive of local elimination. However, in the fall of 2004, five striped skunks (in Flagstaff) and 1 gray fox (approximately 30 km south of Flagstaff) were diagnosed rabid. At least two of the skunks and the gray fox were typed as a big-brown bat variant, indicating the need for a more comprehensive understanding of the dynamics associated with this rabies variant and additional rabies management in the area (Leslie et al. 2006, Weissinger et al. 2005, USDA 2005).



Contraception

Methods for contraception could involve live capture and surgical sterilization (Kennelly and Converse 1997), the use of chemical reproductive inhibitors placed in baits or other delivery devices (Balser 1964, Linhart et al. 1968), or the application of immunocontraception (i.e., vaccines that can cause infertility in treated animals). Suppressing reproduction over time should eventually reduce the size of target species populations and lead to a reduced potential for the spread of rabies by reducing the chances of contact between infected and healthy animals. Contraception would not be useful in meeting the immediate needs of stopping a localized outbreak of rabies (USDA 2004), but may be useful when used in tandem with ORV for long-term rabies management programs.

The idea of immunocontraception for limiting wildlife populations and modulating density-related disease is an intriguing and rapidly progressing area of research, although it is still considered highly experimental (Hanlon et al. 1999a, Bradley 1995, Miller 1997). Interest in oral contraception in wildlife began in the early 1960s as a means of controlling coyote populations causing livestock depredations in the western U.S. and red fox populations responsible for spreading rabies in the eastern U.S. Research efforts with the reproductive inhibitor diethylstilbestrol had promise, but these were abandoned because of the lack of safe, effective, long-lasting agents, and effective delivery systems. Recently, contraception has regained attention as a means of controlling wildlife populations (Hanlon et al. 1999a), particularly those that are abundant and not easily managed by traditional population reduction methods.

Recombinant vaccines that cause a target species to produce antibodies against its own sperm or eggs or that affect reproductive hormone functions have been produced (Miller 1997). Several logistical concerns such as: 1) the durability of the contraceptive vaccines in baits after distribution in the field; and 2) the limitation of current vaccine designs that require baiting an animal population twice, about one month apart, to successfully treat individual wild animals, still need to be addressed before this method could be applied successfully in the field (Miller 1997). In addition, several environmental concerns regarding this strategy still need to be addressed, including safety of the proposed vaccines to humans, other wildlife species, and even nontarget members of the target species (e.g., juveniles that might consume baits) (Miller 1997, Guynn 1997, Hanlon and Rupprecht 1997).

Oral Rabies Vaccination (ORV)

In the early 1960s, George Baer found that foxes in the U.S. could be immunized by oral application of the live attenuated ERA virus (WHO 2005). The discovery, which did not gather much attention until it was presented at a conference in Europe in 1970, became more accessibly published in 1971 (WHO 2005, Baer 1971). Although the concept of ORV to control rabies in free ranging wildlife populations originated in the U.S. (Baer 1988), it has a longer history of implementation in Europe and Canada. ORV programs in several Western European countries, using either attenuated rabies vaccines (modified “live virus” such as ERA) or the recombinant vaccinia-rabies glycoprotein (V-RG) vaccine, have resulted in a terrestrial rabies-free designation in seven European countries (Finland and the Netherlands since 1991, Italy since 1997, Switzerland since 1998, France since 2000, and Belgium and Luxembourg since 2001) (European Commission 2002). ORV remains as the only available technique that either independently or when integrated with other methods shows promise as an effective means of wildlife rabies control on a broad geographic and species scale (Slate et al. 2002).

In North America, the Province of Ontario, Canada expanded research during the mid-1970s to evaluate the prospect of using ORV to eliminate rabies that became established in red foxes in that province during the late 1950s (Baer et al. 1971). Since 1989, the Ontario Ministry of Natural Resources has aerially distributed about 12 million baits containing an attenuated rabies virus (ERA vaccine) that has reduced rabies in foxes by more than 97% (Johnston et al. 1988, Slate et al. 2002). The emergence of raccoon rabies in the eastern U.S. during the 1970s heightened interest in the application of ORV for raccoons. Due to biological and ecological differences among the types of animals that transmit rabies, development of specific vaccine and bait combinations were needed. In contrast to red foxes, which were the focus of ORV programs in Europe and Canada, raccoons were not readily immunized by the oral route with the modified live virus vaccines (Rupprecht et al. 1988).

Oral wildlife vaccination for raccoon rabies control has been under field evaluation in the U.S. since 1990. As a result of field safety testing in the early 1990's, the V-RG vaccine was conditionally USDA-licensed for vaccination of free-ranging raccoons in 1995 and fully licensed in 1997 in the U.S. (Hanlon et al. 1999a). It remains the only effective vaccine licensed for use in the U.S. and Canada for raccoons (CDC 2007a). V-RG was also recently licensed in 2002, for the vaccination of coyotes in the U.S. and Canada (although it is only being used for raccoons in Canada, as canine rabies has not been found in coyotes in Canada). It has also been approved for experimental use by USDA-APHIS, Veterinary Services (VS), Center of Veterinary Biologics for vaccination of gray foxes in Texas (CDC 2007a, Hanlon et al. 1999). Since the first field release of the V-RG vaccine in 1990, the number of vaccine-laden baits that have been distributed annually in the U.S. has risen exponentially, to more than 65 million baits in the eastern U.S. and Texas at the close of 2005 (USDA 2007a).

To eliminate rabies in a local area, an estimated 60 to 80% of the vector population must be vaccinated to sufficiently reduce rabies transmission from infected to susceptible animals within and among species (Robinson et al. 2004, Voigt et al. 1985, Linhart et al. 2002). The idea behind ORV is that when an animal eats a bait it punctures a sachet containing the vaccine. The vaccine is then swallowed and bathes the lymphatic tissue in the throat area and initiates the immunization process. Thus, a successful ORV program requires an effective delivery system.

Spillage of vaccine as an animal consumes a bait is one issue of concern during delivery. In addition, the bait's flavor and attractant must be relatively target specific to enhance delivery. Furthermore, proper ingestion of vaccine baits by target animals depends upon factors in addition to flavor of baits. Not only does the bait and attractant have to be palatable to the target animal, but shape, consistency, and a host of other factors are required (Jojola et al. 2004). Furthermore, the vaccine must be tested to ensure its effectiveness and safety by the oral route in the species to be targeted.

In current U.S. programs, the baits are small blocks of fishmeal (for targeting raccoons and coyotes) and dog food (for targeting gray foxes) which are held together with a polymer binding agent. They are considered "food grade" materials. The baits are rectangular or square in shape with hollow centers. The sachet containing the liquid vaccine is contained in the hollow center of the bait. "Coated" sachets with a simple fishmeal attractant attached to their surface are also used (Linhart et al. 2002) and may be equal in effectiveness at lower cost per vaccinated target wild animal (Slate et al. 2005, USDA 2004). The fishmeal and dog food polymer baits may also contain a tetracycline biomarker which binds to calcium and, therefore, can be found in the metabolically active portions of bones and teeth of animals. Tetracycline deposits can be viewed with a fluorescent microscope. All baits are marked with a warning label that includes a phone number to call for additional information.



In field tests conducted in the U.S., the majority of ORV baits have been consumed within the first 7 to 14 days after placement, with reports of up to 100% of the baits being consumed within a 7 day period (Farry et al. 1998, Hable et al. 1992, Hadidian et al. 1989, Hanlon et al. 1989, Linhart et al. 1994, Steelman et al. 2000, USDA 1995). The likelihood of a bait being consumed is dependent upon several factors, including animal population densities (the diversity and composition of target and nontarget species), bait preference, bait composition, attractants, and the availability of alternative food sources. Baits that are not consumed may remain in the environment for several months after placement, dependent upon environmental conditions (precipitation, temperature, etc.) and the condition of the baits. The V-RG virus that is not consumed by the target species or other vertebrates inactivates over a relatively short time period, depending upon environmental conditions.

In addition to an effective vaccine and bait, success of an ORV program depends on the density and dispersion patterns by which the baits are placed in the field (Bachmann et al. 1990). In current U.S. programs, ORV zones are delineated based on the most current distribution of rabies cases and the expected or predicted direction of disease spread. On an annual or biannual basis, one treatment of ORV is distributed by aircraft (rural areas) or by ground placement (urban and suburban areas). Treatment continues on a recurring basis until the goals of the ORV program are met (USDA 2004). In the eastern U.S., baits targeting raccoon populations are generally distributed at an average density of 75 per km² during the spring or fall months. Aerial bait distribution is typically conducted at about 152.4 m above ground level in straight "transect" flight lines. Currently, parallel flight lines are spaced at a minimum of 500 m to a maximum of 1000 m (USDA 2004).

Vaccination zones are determined in cooperation with state rabies task forces, state health departments, CDC and other state agencies with jurisdiction over vaccine use and application in wildlife and domestic animal species (USDA 2004). Project effectiveness is based in large part on the percentage of ORV baits consumed in populations of target species and the presence of sufficient levels of rabies virus neutralizing antibodies (RVNA) in a large enough percentage of the population to resist the spread of rabies (USDA 2004). Currently, the best measure of success is the absence of rabies cases of the targeted virus variant for a minimum of two years (OIE 2006).

To monitor program effectiveness, target species are live-captured 4 to 8 weeks post vaccination, tested for the presence of tetracycline, weighed, aged, and sexed, and released (if healthy) back into the wild (USDA 2004). Blood serum samples are taken for RVNA antibody testing. Enhanced surveillance (using sick and strange-acting target and nontarget wildlife, nuisance wildlife captured during other wildlife management activities, and road-killed wildlife) is applied within the ORV zones to determine the leading edge of rabies epizootics and distribution for the specific rabies virus variant. Contingency actions may be implemented depending on surveillance findings. Contingency actions may include ORV at "normal" or higher baiting densities or frequencies, TVR, and local population reduction, supported by continuing enhanced surveillance within and outside of the contingency action zone (USDA 2004, USDA 2007b).



Presently, research is being conducted to develop and evaluate effective oral vaccines and baits for use on skunks, mongooses, and feral or free-roaming dogs.

Integrated approach

While ORV is the “anchor method” to rabies control in specific wild carnivores, the overall strategy is typically an integrated one that includes population monitoring, enhanced rabies surveillance, and public education. During emergency outbreaks, contingency actions are also employed that often incorporate several rabies control methods such as TVR, ORV at higher bait densities and greater baiting frequency, and population reduction. For instance, between July and October 1999, an emergency response referred to as “point infection control” (PIC) was implemented to combat an incursion of raccoon rabies into southern Ontario. The strategy involved a combination of TVR, ORV, and population reduction (Finnegan et al. 2002). Through this integrated approach, the number of positive rabies cases has been reduced to one (as of 2006), with emphasis being shifted to enhanced rabies surveillance to determine if raccoon rabies has been eliminated from Ontario. Also, Nassau County (encompassing Long Island), New York; Cape Cod, Massachusetts; and several counties in Ohio experienced rabies outbreaks outside of ORV zones. These outbreaks required contingency actions and underscored the need for an integration of control methods to effectively manage rabies.

A good example of the integration of methods is provided by the response of detecting rabies west of the Ohio ORV zone in 2004. The first case of raccoon rabies was identified in Lake County, Ohio, 10.6 km west of the existing ORV zone. The raccoon variant of the rabies virus quickly spread and cooperative surveillance efforts revealed 45 raccoons and one skunk positive for raccoon variant rabies within three counties (Geauga, Lake, and Cuyahoga) in Ohio from July through the end of December. Prior to the 2004 ORV baiting campaign, the Ohio program had prepared to move the existing 25-mile wide ORV barrier five miles east as the existing zone was considered successful in nearly eliminating raccoon variant rabies from the state. The only exceptions had been isolated cases of rabies occurring in “hot spots” less than one mile from the Ohio-Pennsylvania border. The western-most outbreak triggered a contingency action response, which encompassed a 2,471 km² area in 2004. Thus, a large scale TVR program was implemented in addition to the distribution of 98,565 ORV baits. This event underscored the strong need for enhanced surveillance and public education concerning the translocation of wildlife. The outbreak appears to be contained, with a few remaining cases. TVR may be integrated into the program again in 2007 to try to eliminate the remaining cases and restore the original ORV zone to rabies free status.

The challenge for successful elimination of raccoon rabies in the U.S. involves cooperation and coordination with numerous federal, state and local agencies, tribes, and land managers. Elimination campaigns cannot proceed in isolation. Coordination among states of varying sizes remains critical to long-term success. Re-invasion from neighboring states will always be a risk in the absence of careful coordination. Surveillance and control must be maintained in areas that are determined “free” of rabies. In Germany, elimination of fox rabies has progressed slowly, at least partly because the individual states did not act in concert. In contrast, France achieved rabies-free status within 5 years, at the end of 2000, likely because it had a national program. The use of ORV in Switzerland during the past 20 years resulted in elimination of rabies by 1998 (Blanton et al. 2006). The challenge in North America is to achieve cooperation and coordination between two or more levels of government in and among the three countries. Working closely along shared borders in Canada, U.S., and Mexico should reduce the potential for translocation of wildlife, dogs, and other animals that could spread rabies and provide a platform for enhanced rabies surveillance, critical information sharing and strategy formulation.

Methods for Controlling Rabies in Bats

Education Campaigns in conjunction with Habitat Modification

Approaches to control the transmission of bat rabies to people should include education of the public on topics such as:

- Avoiding potentially infectious contact with bats
- Seeking PEP after exposure
- Preventing bats from establishing colonies in certain sensitive buildings such as hospitals, schools, and homes
- Utilizing habitat modification techniques (i.e., screening or caulking entry/exit holes) designed to prevent access of bats to human living quarters and livestock enclosures
- Utilizing repellents (i.e., lights, lime, sulphur candles, formalin, and naphthalene flakes) to repel bats from human dwellings
- Educating the public on habitat modification techniques can minimize PEP considerations and associated costs
- Obtaining and maintaining preventive immunization for those living in highly endemic areas, including pets
- Recognizing the need to identify and develop programs that may help with bat rabies control (CDC 2007a, Greenhall 1970, Brazuna et al. 2006, Rosatte 1987, WHO 2005)



Managing Vampire Bat Populations and Vaccination of Cattle

The first scientific report on bovine rabies came from Carini in Sao Paulo Brazil in 1911 (Carini 1913). He found the negri corpuscle in bovine brains and was able to replicate paralytic rabies in rabbits with this material. In 1931, Pawan first isolated the rabies virus from various bat species, including vampire bats (Pawan 1936). In 1931, Telles Giron's research showed that the "derriengue" paralytic fatal disease in livestock was caused by the rabies virus (Telles Giron 1945). In the years following this finding, reports of rabies in cattle were confirmed in many Latin American countries.



Early research indicated that vampire bats inhabited tropical and subtropical areas less than 1,500 m in elevation (Greenhall 1970) and latitudes between 33°S and 29°N (Acha 1968). Today, research has shown that vampire bats have expanded their range to include arid and semiarid areas and at elevations up to 2,400 m (Jimenez 2004). This range expansion is in direct relationship to the growth of the livestock industry in Latin America (Greenhall 1970, Jimenez et al. 2006). One important limitation for vampire bats, however, is their inability to survive winter temperatures below 15°C (Acha 1968).

Vampire bat-transmitted bovine paralytic rabies can be controlled by vaccination of susceptible cattle populations. Vaccination is the principal zoosanitary measure recommended by the international community for protecting livestock against rabies (Jimenez et al. 2006). In attempt to prevent and control rabies in livestock in Mexico, employees stationed in endemic areas use Geographic Information Systems (GIS) to identify and record risk areas based on reported rabies cases and to efficiently immunize

livestock as necessary. This system also allows for immediate notification of rabies outbreaks to nearby communities and evaluation of economic impacts of vampire bat-transmitted rabies in livestock (Jimenez et al. 2006; Jimenez 2004, 2007; Shwiff et al. 2006, 2007).

Vaccination alone, however, does not offer protection against daily predation by vampire bats which can lead to devaluation of hides and meat, reduced milk production, infection, transmission of pathogens such as screwworm, malnourishment, inability to nurse young, and death (Greenhall 1970). Thus, an integrated approach to vampire bat control is essential. In 1968, Mexico's National Institute of Livestock Investigation established a cooperative program with the United Nations Food and Agriculture Organization, wildlife agencies in the U.S., the United Nations Development Program, and the U.S. Agency for International Development to evaluate the necessary technology for controlling rabies transmitted by vampire bats. Methods discovered by this cooperative program are still in use in Latin America and are a powerful tool, in combination of vaccination of livestock, for managing vampire bat-transmitted rabies (De Anda et al. 1971; Flores-Crespo et al. 1972, 1974, 1976, 1979).



Various methods have been used in attempt to control vampire bats, such as smoke and fire, lighting, habitat modification, shooting, netting, trapping, and poisoning (Greenhall 1970). However, population reduction by the use of registered anticoagulants is currently the most effective approach to controlling this vector species. Anticoagulants, such as Warafin, Chlorophacinone, and Diphenadione can be applied directly to the backs of captured vampire bats. The animals come into contact with the substance and ingest it during their cleaning activity. In field studies, this method was 90-100% effective in treated colonies (Flores-Crespo and Said 1972; Flores-Crespo et al. 1974, 1976). Six months after treatment, vampire bat roosts were not repopulated and no harm was done to any of the other species of bats that were living in the same refuge. In one case, researchers witnessed dead vampires being eaten by terrestrial mammals with no resultant toxic effect. This is attributable to the fact that vampire bats are very susceptible to anticoagulants and the amount of active substance in the compound is consequently very low (Flores-Crespo and Said 1972; Flores-Crespo et al. 1972, 1974;

Jimenez and De La Torre 2006; Flores-Crespo and Arellano-Sota 1988; Arellano Sota 1993). Application of anticoagulants to vampire bat roosts is considered to be effective, but is not always practical as it is difficult to find and access vampire bat roosts.

Registered anticoagulants can also be applied to cattle intraruminally, by intramuscular injection, or by topical treatment to old bite wounds made by vampire bats. Under field conditions at ranches in two separate locations in Mexico, intramuscular injection of anticoagulants to cattle were shown to reduce vampire bat bites by 87-96% 11 to 12 days after injection. Topical treatment to old bite wounds at three ranches in Mexico resulted in an 81-94.5% reduction in the number of bites 15 days after treatment (Thompson et al. 1971, Flores-Crespo et al. 1979). Pharmacological and toxicological studies of diphenadione, administered intraruminally, and warfarin, administered intramuscularly, showed no adverse effects in cattle (Flores-Crespo et al. 1971, 1976, 1979; Thompson et al. 1971; Arellano Sota

1993). The control methods described is selective for only those vampire bats feeding on cattle. Therefore, haematophagous bats that continue feeding on wild animals rather than cattle will not be impacted by this program. Applied research has demonstrated that there are vaccines available for protecting cattle against rabies and that there are also selective and effective methods of reducing vampire bat populations. Mexico has reported reductions in rabies in cattle by use of these methods (FAO/OIE/WHO 1969, 1979, 1986).

The control of vampire bats is closely linked with the survival of other bat species as numerous species may roost in the same areas. Thus, the necessary control of vampire bats must be based on sound biological and ecological studies so that non-specific methods that indiscriminately destroy haematophagous, frugivorous, and insectivorous bat species are avoided. Genetic research is being conducted by USDA-APHIS-WS National Wildlife Research Center and SAGARPA-SENASICA on bat species and their relationship with the rabies virus with the purpose of identifying the responsible genes that cause susceptibility in vampire populations (Amezcuca et al. 2002, 2005; Jimenez et al 2005; Piaggio et al. 2006). This research could contribute to the protection of beneficial bats in North America, since the study is focused on vampire bats and avoids using nonspecific methods that decrease species of fruit-eaten and insectivorous bats (Jiménez and De la Torre 2006).



Methods for Controlling Rabies in Feral and Free-roaming Dogs

Mass Canine Vaccination by Injection

Mass canine vaccination campaigns have been the most effective measure for controlling canine rabies in developing countries. Approximately 70% of the dog population in each community should be vaccinated in areas where canine rabies is endemic (WHO 2005, Cleaveland et al. 2003, Kayali et al. 2003). In a study on mass canine vaccination in rural, sub-Saharan Africa, the incidence of dog rabies declined by 70% and 97% after the first and second campaigns, respectively, with vaccination coverage of 60-70% of dogs (Cleaveland et al. 2003). This level of vaccination coverage can be achieved through strategies consisting of well-designed educational campaigns, multi-agency cooperation, community participation, local commitment in planning and execution, availability and delivery of recognized quality vaccine, media support, and effective coordination and supervision by the health services (WHO 2005).

Rabies vaccination campaigns are usually conducted annually, but more frequent campaigns may be needed in areas where dog population birth and death rates are high. All dogs and cats should be immunized when brought to the campaign center, regardless of their age or weight. Registration and permanent identification of vaccinated dogs is also recommended (WHO 2005). The use of temporary colored tags or plastic collars has proven useful in identifying vaccinated dogs and has provided motivation for owners to bring in their pets for vaccination. Identification of dogs is necessary to evaluate the vaccination coverage rate and to identify unvaccinated dogs for follow-up measures. In order to apply strategic planning and management, an estimate of the dog population and evaluation of a mass vaccination campaign is required (WHO 2005). Three basic approaches to mass vaccination campaigns have been adopted, either alone or in combination, to control rabies in canine rabies-endemic areas. These approaches include: 1) house-to-house visits; 2) fixed vaccination posts in well-recognized sites within the community; and 3) mobile teams which set up temporary vaccination posts (WHO 2005).

Since the 1970s and 1980s, national mass canine vaccination campaigns have been conducted on an annual basis in Latin America (PAHO 2005). Mexico's vaccination campaign increased annually from 205,000 doses given to dogs in 1970 to 5.5 million doses in 1989, totaling 36.8 million vaccinations between those years (SALUD 2006). By 1989, however, Mexico's federal government determined that such efforts were not sufficient to cover the total estimated canine population. In 1990, the first "National Week of Antirabies Vaccination" for canines was implemented which involved an intensive, broad scale, free rabies vaccination campaign by trained health staff to assure proper and timely application of high quality and quantities of biologics. Through this effort, the number of dogs vaccinated increased each year from 7 million in 1990 to more than 16 million in 2006. As a result of this intensive campaign, canine rabies showed marked decreases from 3049 positive rabies cases in dogs in 1990 to 80 in 2006 (SALUD 2006).



High coverage (more than 80% in Mexico) has been achieved during these intensive campaigns (PAHO 2005, SALUD 2006). The organization of the campaigns is based on multi-agency collaboration, community participation, and strong media support (PAHO 2005). Three committees (national, regional, and local) have been established to handle the technical and logistical aspects of the campaigns. The success and sustainability of mass vaccination campaigns in Latin America have been the result of several factors such as political commitment, acquisition and supply of canine vaccines by the ministries of health, free delivery of vaccines, local-level commitment in the planning and execution of the campaigns, and effective coordination and supervision by the health services (WHO 2005, PAHO 2005, PAHO 2004).

Dog Population Management and Animal Birth Control (ABC) Programs

There is no evidence that removal of dogs alone has ever had a significant impact on dog population densities or the spread of rabies. The population turnover of dogs may be so high that even the greatest recorded removal rates (about 15% of the dog population) are easily compensated for by increased survival rates. Population turnover leads to a decrease in herd immunity, which can actually increase the incidence of rabies.

Furthermore, dog removal through lethal means may be unacceptable to local communities and can lead to the failure of rabies control programs (WHO 2005, Kayali et al. 2003).

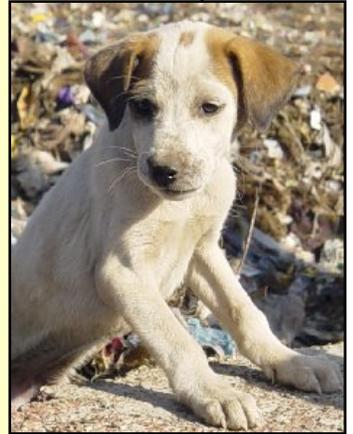


One recent example of public outcry in response to dog population management is the clubbing of more than 54,000 dogs in southwest China's Yunnan Province in July, 2006. In response to a rabies outbreak in dogs and the diagnosis of several human rabies cases, the Chinese government ordered the mass extermination of dogs, including those which

had been properly vaccinated (The New York Times 2006). Even in the midst of community protest due to the inhumane and barbaric nature of the campaign, mass extermination schemes began to surface in other areas of China as fear of human rabies cases spread. For instance, in August 2006, a cluster of 16 villages in the southwestern part of Shandong Province declared a rabies alert and county officials drafted a dog extermination plan that called for the clubbing death of any dog found within a three-mile radius of any known rabies case. Although Chinese citizens publicly protest this type of mass extermination, the Chinese government and vigilantes continue the practice (The New York Times 2006).

The targeted and humane removal of unvaccinated, ownerless dogs may be effective when used as a supplementary measure to mass vaccination, however (WHO 2005). Three practical methods of dog population management are recognized and include movement restriction, habitat management, and reproduction control or ABC (WHO 2005). Attempts to control dog populations through culling, without alteration of habitat and resource availability, have generally been unsuccessful. Since the 1960s, ABC programs coupled with rabies vaccination have been advocated as a method for controlling free-roaming and feral dog populations and, ultimately, human rabies. The rationale is to reduce the dog population turnover as well as the number of dogs susceptible to rabies and limit aspects of male dog behavior (such as dispersal and fighting) that facilitate the spread of rabies. Population reduction of dogs during these programs, however, may be counterproductive as unidentifiable sterilized, vaccinated dogs may be destroyed (WHO 2005). ABC programs have been launched in several countries and the results have been encouraging, with a reported reduction in the size of the urban feral and free-roaming dog population and the number of human rabies cases. However, data are limited and independent evaluation of projects has not yet been undertaken (WHO 2005).

Managing the canine overpopulation problem is of immediate concern in Mexico as large numbers of dogs living in close proximity to the human population, especially in extreme poverty conditions, increases the risk for disease spread and potential for attacks. To confront this problem, a culture of “Responsible Ownership” is being taught through a partnership between county authorities, animal protection groups, and Schools of Veterinary Medicine - all coordinated by the Ministry of Health. “Responsible Ownership” attempts to promote the safe cohabitation of pets, the nuclear family, and society while helping to reduce and eliminate ownerless street dogs (SALUD 2007).



This strategy involves two lines of action:

1. Sterilization of dogs and cats and promotion of voluntary donation of unwanted dogs and cats for humane euthanasia.
2. Emphasis on the information campaign to promote the practices of “Responsible Ownership” in different sectors of society.

In 2006, 812,000 control actions were conducted; 85% for euthanasia and the remainder for sterilization. For the reporting period of 2001-2006, 1.2 million ownerless dogs were humanely euthanized and 192,000 were sterilized (SALUD 2006).

This program has been well-received and requested by the community, but modifications continue to be made to increase participation of pet owners in the program. As the program evolves, additional infrastructure and the hiring of professional staff is needed



to support these activities in the Sanitary Districts that are experiencing canine overpopulation, such as is found in marginal and rural areas. Experts are also needed that are able to evaluate the impact of information campaigns and propose new alternatives. The program could also benefit from specialists versed in the development of methodologies to estimate the reduction of dog and cat birth rates and associated economic repercussions (SALUD 2007).

ORV for dogs

An active campaign to reduce or eliminate rabies includes a vaccination program for dogs. In many areas of the world, it is estimated that only 30-50% of dogs are vaccinated and on some Native American reservations in the U.S. vaccination rates may be as low as 5 to 20%. At these vaccination rates, it would be difficult “to break the rabies cycle” should rabies be introduced into a naïve population. Reasons for low vaccination rates may include lack of interest, lack of known rabies cases, lack of knowledge, cultural viewpoints, or the cost or availability of vaccines (Bergman et al. 2004).



Oral vaccination of dogs offers a new approach that could significantly improve dog vaccination coverage globally, especially of free-roaming, feral, and poorly supervised dogs, when applied either exclusively or in combination with parenteral vaccination. Acknowledging the limitations of the parenteral route for canine rabies elimination, WHO (2005) initiated studies on oral vaccination of dogs and the development of safer and effective vaccines and baits for such vaccination. Although the preferred vaccine for immunizing dogs should be parenteral, ORV could be used whenever there is high population of inaccessible dogs. Further field studies to evaluate bait matrix, delivery, economy, efficiency and effectiveness, and safety are encouraged. Strategies for ORV bait dispersal must be studied further as new innovations are required for economical distribution (WHO 2005).

An effective vaccine (V-RG) has been developed for coyotes and foxes in the U.S. and is currently used in rabies management programs in Texas with success. Thus, the same vaccine should be efficacious for dogs as they are also members of the family *Canidae*. However, an oral vaccine has not been licensed for dogs in Canada, U.S., or Mexico. Research on bait formulations for dogs is still in progress. Studies to determine the most effective and preferred ORV bait for feral and free-roaming dogs have been in progress since 2003 on Navajo and Hopi Nations in the U.S. (Bergman et al. 2004). Results of these field trials indicate that the most effective bait formulation currently commercially available is the coated sachet, which has a 79% uptake rate compared to all other placebo baits tested (e.g., Ontario Slims by Artemis Technologies and fishmeal polymer baits, dog food polymer baits, and fishmeal-coated sachets by Merial Limited). Continuing field trials are necessary to support these results (Bergman et al. 2004).

During 2005 and 2006, vaccine efficacy field trials were conducted on the Navajo Reservation in Arizona under a research protocol entitled, “*Rabies Vaccine, Live Vaccinia Vector (USDA Project Code 1901:RO): Feasibility of Raboral V-RG® Delivered in Tetracycline-Coated Sachets as an Experimental Oral Rabies Vaccine in Feral/Free Ranging Dog Populations of Arizona.*” The objectives were to: 1) evaluate the effectiveness of V-RG delivered via coated sachet baits to populations of free-roaming dogs; and 2) evaluate the incorporation of tetracycline in the exterior bait coating as a biomarker in dogs. The field trial site comprised rural land use with areas of human development, primarily single-family homes. Approximately 500 coated sachets containing V-RG were distributed by hand to individual dogs over a one month period in April of each year. All baits were marked with a warning label that included a toll free telephone number to call for additional information; however, any bait not consumed during observation was recovered from the environment. Results are pending analysis.

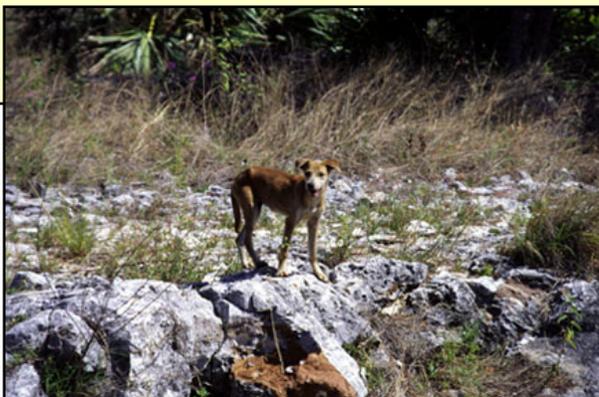


Integrated Approach for Dogs

Effective animal vaccines that provide a considerable duration of immunity have been developed and mass parenteral vaccination programs continue to be the foundation of canine rabies control. As discussed previously, dog destruction alone is not effective in controlling rabies. The principal challenge is effective delivery of vaccines to ensure adequate vaccination coverage in the reservoir dog population. Studies on Latin American dog populations have shown that in many communities a substantial proportion (at least 60–75%) of the total dog population is accessible for parenteral immunization (WHO 2005, Kayali et al. 2003, Cleaveland et al. 2003). In communities where dogs are less accessible, such as in rural areas with large populations of ownerless dogs, oral rabies vaccination may provide a potential supplementary strategy. Vaccination coverage of 70% has been sufficient to control canine rabies in several settings, but the exact level of coverage required is likely to vary according to the demographic, behavioral, and spatial characteristics of the dog population. During the last two decades, a significant reduction in human rabies has been achieved in Mexico, South America, and the Caribbean by Pan-American Health Organization (PAHO) and World Health Organization (WHO) programs targeting the elimination of canine rabies (WHO 2005, Matter 2000).

To ensure effective coverage, vaccination programs should consider the local ecology of the dog population, involve coordination of related sectors, and incorporate culturally appropriate education efforts. Paramount to the success of campaigns in Latin America has been the central role played by the public health sector as a lead agency and community involvement and empowerment in rabies management activities. Canine rabies control programs should incorporate three basic elements, with priorities varying according to the prevailing social, cultural, and economic factors. These elements include epidemiological surveillance, mass vaccination, and dog population control. They require community participation, managerial skills, and legislation (WHO 2005, Matter 2000).

Mexico's plan for elimination of canine rabies involves an integrated approach consisting of surveillance and monitoring, mass parenteral vaccination, sterilization, and humane euthanasia. Oral rabies vaccination and contraception are also being considered for dog populations in rural areas that lack infrastructure or have a high degree of marginalization. The following strategies are used to disrupt the transmission of rabies and eventually eliminate the disease in dogs and humans: 1) Disruption of rabies virus circulation through the strict control of suspect rabies cases or foci; 2) Certification and verification of the elimination of canine rabies transmission; 3) Stabilization of the canine population through sterilization, humane elimination, and "Responsible Ownership" education campaigns (SALUD 2007).



V. Joint International Ventures

Implementation of International Cooperative Venture

Rabies impacts public health, society, agriculture, and wildlife. Consequently, federal, tribal, state/provincial, and municipal authorities concerned with human health, the livestock industry, companion animals, and wildlife have partial jurisdiction and vested interest. No single agency has total authority for rabies control. This dispersed authority can be a hindrance in establishing effective management programs and exposes the fragility of interdepartmental and transnational cooperation, especially where substantial budget issues are involved (MacInnes and LeBer 2000). In addition, the subject is sufficiently complex that no single agency understands the full extent of problems and solutions that may be faced by other agencies. Furthermore, with budget challenges and changing priorities, it is easy for officials to declare rabies control another agency's problem. This lack of accountability may result in delayed action (MacInnes and LeBer 2000).

Most wildlife agencies have some mandate to protect public safety, but because of the safety net of PEP for humans, direct intervention may not be perceived as necessary. However, treating the problem at its roots, by eliminating rabies from wildlife vector populations, could ultimately result in cost savings for local, state/provincial, tribal, and federal governments. Rabies also can complicate the management of nuisance animal complaints and policy regarding rehabilitation of wildlife. In fact, the rabies issue has strained relations between wildlife rehabilitators and government wildlife agencies throughout the regions affected by raccoon rabies in the eastern U.S. since 1977 (MacInnes and LeBer 2000).

Given that an effective rabies prevention system exists for many species, to allow such a system to go unused because of expense would be unacceptable to the public. Thus, the decision of whether to embark on managing rabies in wildlife is not in question. What is in question is "how" it can be achieved. Because rabies-human interaction has multiple dimensions, the decision requires complex arguments and rigorous reasoning. Cooperation among the many involved agencies is essential (MacInnes and LeBer 2000).

The North American Rabies Management Plan, therefore, is designed to foster international cooperation involving governments at all levels, indigenous groups, nongovernmental organizations, corporations, universities, and private citizens. Ultimately, success of the Plan depends on effective partnerships among all segments of society that have a role in rabies management. This voluntary effort requires leadership at different levels, including biologists, veterinarians, research scientists, budget analysts and economists, administrative specialists, interagency liaisons, and local, regional, tribal, and national managers. These institutional arrangements transcend a diversity of political structure, culture, and language, and have allowed continuous growth in the field of rabies management.

Commitment by Plan Partners

The lead body for the Plan is the Planning Team, composed of representatives from Canada, U.S., and Mexico. The Planning Team provides leadership by stewarding the Plan, working with Plan partners to assure the quality of Plan activities, advocating for rabies management policies and programs with appropriate stakeholder groups, and facilitating communication throughout the Plan community.

While agencies provide guidance and long-term management of the Plan in each country, it is the network of partnerships that connect the various members of the rabies community. Plan partners have key roles in attaining the vision and goals of the Plan and they do so through the national and regional joint ventures in Canada, U.S., and Mexico. These self-directed national and regional groups connect diverse programs aimed at rabies control on both public and private lands.

Vision, leadership, sufficient resources, and continuity are all essential for success. But without sound science, biological monitoring, and adaptive feedback, efforts in rabies management will not be effective. The Plan's science support team and technical committees, comprised from joint ventures and other partnerships, are all critical to ensuring progress. Ensuring that these different administrative and technical groups work together to achieve what is promised in the Plan's visions and objectives is imperative.

Because the Plan works continentally, regionally, at the state/provincial level, and locally, adaptive management and strategic planning must also occur at multiple spatial scales. The spatial scale determines the relevant questions, challenges, opportunities for learning, and possible inferences. Managers at all levels benefit from efficient informational sharing.

To manage adaptively, managers must be able to articulate clear, quantifiable objectives for each action; predict the biological outcomes of management actions; design and implement monitoring procedures to measure those outcomes; and compare outcomes with the original predictions and objectives. Knowledge gained during one cycle is then used to adjust future planning and implementation. The monitoring and evaluation components may vary from simple monitoring of the results of routine management to rigorous experiments of alternative management options.

Several priorities have been identified for rabies management programs in Canada, U.S., and Mexico to succeed, which all rely on effective and efficient coordination and collaboration. These priorities include: improved or new oral vaccines and/or baits to reach target species, optimized ORV strategies, effective communication, strategies to limit translocation and population growth, and access to sufficient long-term funding. These key priorities must be addressed to ensure that rabies management has the optimal chance of achieving long range programmatic goals of eliminating specific variants of rabies virus in North American terrestrial carnivores (Slate et al. 2005).

VI. Increasing our Scientific Base

Commitment to Expand Scientific Information to Close Critical Data Gaps

The Plan community is committed to expanding scientific information where it is lacking or not well defined and integrating the best possible science into the Plan's decision-support systems from continental to regional to local project scales. Commitments will be needed by Plan partners or outside funding sources to foster and finance new scientific capabilities which will strengthen the biological foundation of the Plan. The Plan's scientific base needs to be improved to provide a better understanding of population and disease trends and the biological effectiveness of Plan actions. Improving the cost-effectiveness of Plan actions and strengthening the scientific foundations of rabies management plans are crucial to maintaining the Plan's leadership role in successful rabies management.

Framework for potential collaboration among countries to close critical data gaps:

1. Information transfer – communication (i.e., bi-national meetings, scientific publications, routine email correspondence on rabies-related issues)
2. Research (i.e., gray fox movement study, feral dog ORV field trials, skunk bait formulation and vaccine development)
3. Surveillance and monitoring (i.e., recent animal collection and direct rapid immunohistochemical test [dRIT] training in Laredo, TX; RabID and SIGE-SIVE; Border Infectious Disease Surveillance [BIDS] for coyote virus elimination on TX/Mexico border)
4. Transborder rabies management (i.e., Canada-U.S. border raccoon rabies control using ORV)

Conferences, such as RITA, bring together scientists; academics; wildlife, agriculture, and public health officials; and other specialists from numerous countries in the Americas and other continents to share developments in the field of rabies management. Topics include fundamental studies on rabies virus and its pathogenicity, diagnosis, surveillance and epidemiology, studies on the biology of rabies reservoir species, and experiences with animal rabies control and human prophylaxis.

RabID and SIGE-SIVE, are GIS-based surveillance mapping tools which provide nearly real-time access to spatial-temporal rabies distribution data that include results from enhanced rabies surveillance submissions (USDA 2005a, Blanton et al. 2006, Rupprecht and Slate 2006). RabID and SIGE-SIVE can, therefore, be used as common and secure platforms for transborder information sharing, allowing for bi-national opportunities for surveillance and monitoring.

dRIT allows rapid diagnosis of animals under field conditions (Lembo et al. 2006, CDC 2006). This program can be used to enhance surveillance and can then be stored in a database, such as RabID, that is available to all Plan partners.

Additional data gaps (Hanlon et al. 1999a):

- A better understanding of the complex interaction of host factors (e.g., density dependent changes in reproduction, survival, and dispersal, and level of immunity in the surviving population) and viral characteristics involved in epizootic and enzootic transmission of rabies in wildlife populations is necessary.
- Species identification of animals submitted for rabies testing should be conducted by trained diagnostic laboratory personnel or through collaboration with mammalogists to correct potential laboratory personnel limitations with regard to taxonomic classification of animals. Information on specific geographic location and disease status of all animals submitted for testing should be reported and retained.
- In addition to rabies surveillance of wildlife through conventional public health submissions, strategic application of active (enhanced) surveillance, such as at epizootic fronts and in areas implementing ORV, are critical. Existing surveillance systems should be integrated within geographic information system databases, especially databases that would enable classification of habitat features. This would facilitate the understanding of the population dynamics and habitat relationships of reservoir species and potential spread of disease.
- Explicit descriptions of the impact of rabies on the population structure and dynamics of carnivores and the potential effect of interventions, such as ORV, are fundamentally lacking and critically needed.
- Educational materials for the public on rabies in wildlife and potential control measures also are inadequate or lacking. These materials need to be compiled and made available for widespread public distribution as requested by the public.
- Public education programs should be developed to explain health risks and the need for regulations on translocation of wildlife.
- Effective vaccines that generate immunity to rabies or inhibit reproduction in specific species are needed.
- Effective and efficient baits and bait delivery systems should continue to be developed (OMNR 2007).
- Professional societies with diverse interests should collaborate and inform their members of activities in related fields through solicited papers and symposia.
- Symposia that bring veterinarians, wildlife managers, and other stakeholders together for collaboration on management strategies should be conducted.

- The potential benefits of ORV and other integrated control strategies should be thoroughly described for various major application strategies, such as suppression of local intensity of rabies, containment of an epizootic front, and proposed elimination of a terrestrial rabies variant.
- Research leading toward the development of practical contraceptives or related technology for managing wildlife populations should be encouraged and supported.
- Stronger and more uniform federal and state wildlife regulations and guidelines are critically needed to prevent indiscriminate international, interstate, and intrastate movement and release of wildlife, especially rabies vectors, by the general public.

Bat rabies – a potential confounding rabies control factor:

The prospect of effective ORV programs for bats appears remote at this time, given the need for novel, coordinated strategies to reach commensal species. For example, bats have virtually unlimited access to refuge in houses and other dwellings, and this is but one of several challenges. Nevertheless, transmission of rabies from bats to terrestrial carnivores may be the source for some extant rabies variants in carnivores, adding to the complexity of achieving long-term rabies management goals for terrestrial rabies. Documentation of big brown bat (*Eptesicus fuscus*) rabies virus spillover into skunks near Flagstaff, AZ, with up to 19 skunks infected prior to intervention with TVR, represented an unprecedented, contemporaneous event supporting the thesis that terrestrial rabies variants could evolve from virus host shifts from bats to terrestrial carnivores. This event underscores the importance of subtyping rabies cases to facilitate timely identification of potential spillover to nonadapted species. Adequate enhanced surveillance (i.e., beyond public health surveillance focused on potential or actual human exposures to the rabies virus) and differential virus variant diagnosis in bats and carnivores will continue to be required to trigger implementation of ORV contingency plans to address potential emergence of new terrestrial variants of the rabies virus (Slate et al. 2005, Rupprecht et al. 2006, Leslie et al. 2006).

Enhance Laboratory and Field Rabies Diagnostic Methods

Laboratory Diagnostic Methods

Rabies surveillance is still inadequate in many countries and this deficit should be addressed by national and regional authorities. Rabies can only be reliably diagnosed by laboratory tests (OIE 2005, WHO 2005). Thus, laboratory capacity should be developed and/or improved to permit effective rabies surveillance in countries where diagnostic facilities are inadequate or lacking. Epidemiological data should be collected, processed, analyzed, and disseminated rapidly and efficiently between different administrative levels and sectors of government (OIE 2005, WHO 2005). Currently there is not a well documented process in place that allows for a systematic coordination of laboratories. The implementation of the NARMP would promote increased communication and coordination among laboratories in the three countries. In the interim, the national reference laboratories in each country should serve as the primary contact for the implementation of the plan. The contacts include Dr. Charles Rupprecht, Centers for Disease Control and Prevention (Atlanta, GA, USA), Dr. Alex Wandler, Canadian Food Inspection Service (Ottawa, Ontario CA) and Dr. Celia Mercedes Alpuche Aranda, National Institute of Diagnostic and Epidemiological Reference (InDRE) CENAVECE/SALUD (Mexico City, Mexico).

Surveillance of rabies is the basis for any program of rabies control. Veterinary surveillance of rabies and laboratory submission of reports of suspected animal cases are also essential for management of potential human exposures. The emphasis of surveillance should be on the laboratory confirmation and effective reporting of human and animal rabies cases (OIE 2005, WHO 2005). Surveillance of areas in which laboratory-confirmed cases in animals are reported should be encouraged. Attempts should be made to isolate rabies viruses for characterization of prevalent variants. This task should be conducted in designated and well-equipped local, state, provincial, or federal laboratories (OIE 2005, WHO 2005).

Reporting of laboratory-confirmed human rabies cases alone may lead to a severe underestimation of the true number of human cases, resulting in a low priority being given to rabies control. The number of people seeking and receiving post-exposure prophylaxis should be reported in order to provide additional epidemiological information on disease burden and to evaluate the effectiveness and cost-benefit ratio of rabies control programs. Updated systems of rabies reporting should be adopted, especially for the investigation of rabies outbreaks and identification of the rabies virus variants involved, in view of increased international travel and transfer of animals (WHO 2005).

Field Diagnostic Methods

Rabies is viewed as a density-dependent disease, and population dynamics of reservoir hosts are regarded as critical to understanding and modeling the temporal and spatial patterns of rabies in wildlife. In part, the rate of spread of rabies in populations of a particular species can be related to, or modeled by, its social structure, dispersal patterns, and contact rates. Habitat features, such as continuity and patch size, may play a role in the rate of spread and persistence of the disease. Furthermore, interactions among and between species complicate the understanding of the ecologic and epidemiologic factors associated with rabies (Hanlon et al. 1999a).

Collaborate in Research to Improve the International Rabies Management Program and Ensure that Future Management Decisions are Well-informed

Given limited financial resources for managing rabies in North America, strong cross-border communication is imperative. One of the benefits of the Plan is that it will drastically improve communication capabilities by identifying avenues for collaboration. As an example, V-RG could not have been licensed without the close collaboration between Canada and the U.S. The three countries must continue to work closely to find additional effective oral vaccines and baits. The Plan should facilitate the use of ORV in Mexico by the sharing of rabies management-related manuals (e.g., USDA-APHIS-WS ORV Best Practices Manual), training programs, data, and assistance from the U.S. and Canada. The Plan also helps to break down language barriers by ensuring it is translated into English, Spanish, and French, and serves as the catalyst to convert other rabies management-related documents into the three primary languages of North America. The Plan Committee effectively deals with the language barrier by the use of on-site interpreters during planning meetings. Outside the meeting setting, national liaisons must be able to effectively communicate Plan needs and must continue to utilize interpreters. Development of a central trilingual North American rabies website has been discussed as an option as well.

Vaccine and Bait Research

To eliminate rabies in a local area, an estimated 60% to 80% of the target population must be vaccinated to sufficiently reduce rabies transmission from infected to susceptible animals. To control rabies in wildlife populations, researchers continually work to make ORV baiting and vaccine delivery more effective and efficient. Many factors combine to make baiting systems effective. Primarily, the bait must facilitate vaccine delivery to the oropharyngeal mucosa of the target animal. To achieve this an ideal bait must: 1) be attractive and be consumed by the target species; 2) elicit a chewing response to adequately rupture the vaccine container; 3) withstand the impact of aerial distribution; 4) protect the vaccine from UV radiation and other environmental elements; and 5) be cost effective for the purchasing/dispersing agency (Robinson et al. 2004).

Vaccine efficacy is determined in laboratory experiments, typically by following guidelines from international organizations and national legislation; though the target population in the field, affected by all kinds of immunocompromising conditions, may not be as responsive as animals tested in the laboratory. Baits must be designed to release the vaccine onto a susceptible target tissue of the bait consumer. A vaccine that is inactivated by the acidic digestion process in the stomach must be delivered into either the oral cavity to infect cells in the oropharyngeal mucosa or tonsils, or the baits must protect the vaccine from passage through the stomach and release it into the small intestine (WHO 2005).

Spatial and temporal bait distribution patterns strongly influence the proportion of the target population that consumes the baits within the time-limits of vaccine degradation. Only a fraction of all baits deposited during a baiting campaign are picked up by the target species. The number of baits removed by competitors depends on bait specificity; however, even a very specific bait may not be attractive enough to ensure sufficient bait uptake by the target species. Attractiveness of a bait may change among habitats, as each habitat offers a different range of food choices (WHO 2005), thus underscoring the importance of field research on target/nontarget species bait preferences and bait densities needed in a specific area.

Vaccine and bait selection

Vaccine efficacy in the target species must be considered. Preference should be given to vaccines with reduced (non-rabies related) pathogenicity, such as recombinant vaccines (V-RG) or a highly attenuated live virus strain (SAG2), over more pathogenic attenuated live viruses for oral immunization of wildlife and feral, domesticated species such as dogs (WHO 2005). Both target and nontarget wildlife populations should be considered during rabies management programs in order to determine the most effective baiting method available for maximizing vaccine bait discovery and ingestion by the vector species (Linhart et al. 2002).

Epidemiological data based on reliable surveillance and laboratory studies of rabies cases in target and nontarget species must be available before field trials are initiated. Estimates of target population size and bait biomarker background in target species should be obtained before vaccination (WHO 2005, Hanlon et al. 1989). The potential effects on nontarget species, particularly threatened and endangered species, must also be evaluated. For dealing with possible or perceived adverse events of recombinant vaccines, such as reassortment with similar animal viruses circulating in nature, it is advisable that the prevalence of agents related to the vector viruses in target and nontarget species populations, as well as their propagation in previously unrecognized hosts, be monitored (WHO 2005).

Oral animal vaccines

Modified live-virus vaccines

Several types of modified live-virus vaccines with various levels of attenuation have been developed for oral immunization of animals over the past 20 years; however, only 5 have proved suitable for use in the field for vaccination of foxes (Canada and Europe) and raccoon dogs (Europe). These vaccines are derivatives of the original SAD virus (WHO 2007).

- Four SAD-related vaccines (ERA, SAD-Bern, SAD-B19, and Vnukovo-32) have been found to retain some virulence in adult mice and other rodent species. They do not appear to be pathogenic for North American and European carnivores and other large mammals, except possibly for skunks, when they are given by the oral route (WHO 2007, Lawson et al. 1989, Vos et al. 2002).
 - The SAD-Bern vaccine was used in the first large-scale field trial ever conducted. Between 1978 and 1990, 1.3 million such baits were distributed in Switzerland. Continual surveillance led to the detection of three cases of vaccine-induced rabies. No other vaccine-related deaths were noted in over 900 animals examined (WHO 2007).
 - The SAD-B19 vaccine has been widely used in the field. Since 1983, millions of baits containing this virus have been distributed in Europe with no reported deaths among nontarget species (WHO 2007, Muller et al. 2001).

- SAG vaccines (i.e., SAG1, SAG2) are a deletion mutant of SAD developed using selected monoclonal antibodies. SAG vaccines have not been found to be pathogenic in adult mice or other wild rodents tested by the oral, intramuscular or intracerebral routes; however, it is pathogenic for suckling mice when given by the intracerebral and oral routes. SAG vaccines have been distributed in certain Western European countries, Canada, and the Russian Federation (WHO 2007, Cliquet et al. 2006). Laboratory research conducted with SAG2 shows that it is a promising candidate vaccine that may satisfy both safety and efficacy concerns for oral rabies immunization of major North American rabies reservoirs such as skunks and raccoons (Hanlon et al. 2002).

Live recombinant vaccines

A recombinant vaccinia virus expressing the glycoprotein gene of rabies virus (V-RG) was developed by inserting the cDNA of the glycoprotein of ERA strain into the thymidine kinase gene of vaccinia virus (Copenhagen strain). When administered orally, a median tissue-culture infective dose of V-RG elicits titers of virus neutralizing antibodies and confers a protective immune response against rabies virus challenge in a number of carnivorous or omnivorous mammalian species (i.e., red and arctic foxes, coyotes, raccoons, raccoon dogs, domestic dogs, and golden jackals). The recombinant virus expressing V-RG does not exhibit residual pathogenicity caused by rabies; however, it shares basic properties with its parental virus, the human smallpox vaccine strain vaccinia Copenhagen. Safety studies conducted in over 50 mammalian and 10 avian species have not revealed any residual pathogenicity (Rupprecht et al. 1992, Pastoret et al. 1995). Only one report of a clinical adverse reaction has been documented in humans (Rupprecht et al. 2001). The case involved spontaneously cleared skin lesions in a person with assumed increased susceptibility to the vaccinia virus as a result of exposure to the vaccine, through a bite while attempting to remove a partially-chewed vaccine bait from a dog's mouth (Rupprecht et al. 2001). More than 75 million doses of V-RG have been used with success in containing or reducing wildlife or canine rabies in a variety of animal species such as red foxes (Belgium, France, Israel, Luxemburg and Ukraine), raccoon dogs (Republic of Korea), coyotes, raccoons, and gray foxes (Canada and U.S.) and domestic dogs (Sri Lanka) (WHO 2005).

The ONRAB oral rabies vaccine, comprised of the AdRG1.3 vaccine and Ultra-lite bait, was recently developed and field tested through collaborative partnerships between OMNR, Canadian Food Inspection Agency, and many others. Preliminary results show effectiveness in skunks, along with other rabies vectors such as raccoons and foxes. In the summer of 2006, 200,000 vaccine baits were dispersed over four 256 km² plots in Gray and Dufferin counties in Ontario. Samples were collected in the fall of the same year and results are pending (McAllister 2006).

Strategy considerations for ORV targeting terrestrial carnivores

Access to highly immunogenic oral vaccines, together with optimal baits for their delivery, are critical strategic components to ORV. Nevertheless, there is a myriad of spatial, temporal, environmental, and other issues that also impact ORV effectiveness.

Some of the more important issues include:

- Time of year to conduct ORV
- Annual frequency of ORV
- Bait density
- Baiting distribution patterns
- Baiting methods (i.e., aerial, ground, or hand baiting; urban baiting stations)
- Nontarget competition for baits
- Habitat-specific preferences of reservoir species
- Rabies reservoir species population densities
- Multiple reservoir species inhabiting same area

These issues continue to represent a strong challenge to achieving rabies management goals. Thus, meeting long-range goals may require a paradigm shift from ORV as a single tactic toward evaluation of integrated strategies that may include contraception, reduction in access to food subsidies (i.e., reduced habitat carrying capacity for rabies reservoir species in specific environments), and local population suppression. While studies have focused on some of these issues in North America, site specific and regional influences associated with these variables are not well-documented (Slate et al. 2005, Rupprecht et al. 2006, Totton et al. 2002).

Integrate the Contemporary Scientific Findings into Applied Management Practices

ORV Project Decision-making

Project planning

Considerable project planning must precede the distribution of baits, and related administrative activities will vary in structure and detail depending upon political and other variables. Planning and organization are vital to the success of the project. The project should be based on a comprehensive plan that provides alternatives and justification for action, describes the objectives, technical and organizational details, budgetary requirements, and defines the responsibilities of the collaborating institutions (WHO 2005). A project proposal should also include background information on the geographical area to be covered using ORV, estimated costs and benefits of the project, timing, safety considerations, methods of pre- and post-baiting evaluation and relevant data on the target and nontarget populations. The proposal should be distributed to the institutions concerned, well in advance of the proposed start date, for consideration and evaluation (WHO 2005). If several geographical locations are available for the implementation of baiting campaigns, priority should be given to those surrounded by natural barriers and/or those offering community cooperation and logistic support. The rabies situation in neighboring areas should also be taken into account. The selected areas should be readily accessible to government veterinary and medical services. To guarantee effective control of rabies, the size of the vaccinated area should reflect the ecological and epidemiological attributes of the specific situation, such as the home range and movement patterns of wildlife populations and geographical characteristics of the area (WHO 2005).

Implementation

Implementation of ORV projects requires logistical support to ensure bait and vaccine integrity and processes that allow the distribution of adequate numbers of baits to cover large areas (WHO 2005). In addition, the following may be required (WHO 2005):

- Community participation should be encouraged through information, promotional campaigns and, in some instances, training for baiting and disease surveillance.
- Awareness of the campaign among medical and veterinary practitioners is important so that appropriate measures can be taken in the event of accidental exposure to the vaccine. A medical/veterinary advisory group should be established.
- Sampling of specimens should be conducted under appropriate conditions. Trained personnel and adequate laboratory facilities should be available for campaign evaluation, estimation of bait biomarkers and serological determination in the target species, and continuation of rabies surveillance.
- Specialists should be assigned to investigate the epidemiological situation in both humans and animals before, during, and after the implementation of the project and to report to the responsible authorities on a regular basis. After each campaign, evaluation of results is of utmost importance in order to adapt future strategies.

Evaluation

ORV baiting campaigns employ several methods of evaluation (WHO 2005):

- Testing for the occurrence of bait biomarkers (i.e., tetracycline) in target species
- Examining sera from the target species for RVNA
- Analyzing the prevalence of rabies before, during, and after the program

Rabies surveillance plays a critical role in the planning, implementation, and evaluation of rabies control programs. Before ORV programs are implemented, rabies surveillance is usually sufficient. Experience in Europe has shown that the intensity of surveillance activities decreases as successive cycles of ORV campaigns are completed (WHO 2005). Adequate surveillance is most important during this phase; the absence of rabies requires verification, and residual foci of rabies must be detected and delineated rapidly. Animal samples, particularly from those that are sick, acting strangely, or found dead, should be collected to monitor the impact of vaccination (WHO 2005). When monitoring the efficacy of ORV programs, using such tools as biomarker detection, serological testing, and rabies incidence, a minimum of four target animals per 100 km² should be investigated annually. To promote active rabies surveillance in areas where ORV campaigns have been successful, procedures for international certification of the rabies-free status should be established (WHO 2005).

International cooperation in ORV programs

International cooperation in border areas is essential at all levels to achieve effective control programs. Neighboring countries should carefully coordinate their activities along common borders. If baiting campaigns reach a country border, local administrative staff from both countries should coordinate efforts (WHO 2005). ORV generates new epidemiological and ecological concerns within and beyond national borders. For this reason, planning, implementation, and evaluation of campaigns should be coordinated at national as well as international levels. Preliminary contacts should be made with neighboring countries when ORV policy is determined; these contacts should be maintained through regular regional meetings until the disease has been eliminated (WHO 2005).

VII. Challenges

Progress has been made in applying ORV to contain and eliminate some variants of the rabies virus in carnivores in North America. Notable examples include near elimination of rabies from red foxes in southern Ontario (including spillover benefits of elimination in Quebec and the northeastern U.S.), containment and elimination of canine rabies in coyotes from south TX, prevention of raccoon rabies spread through the Lake Champlain Valley in NY and across northern VT and NH, and reduced incidence of rabies cases where other sizable ORV projects targeting raccoons have occurred in the U.S. Both Ontario and New Brunswick have been raccoon rabies-free for more than 10 months and 2 years, respectively, after implementation of “point infection control” strategies, but continued surveillance is critical to monitor project effectiveness (Rosatte et al. 2001, Slate et al. 2005).

While ORV programs show promise, several challenges need to be addressed to better ensure that the long-term programmatic goal of rabies elimination in terrestrial wildlife may be achieved (Slate et al. 2005). To date, several challenges have been identified and initiatives have been taken toward (Slate et al. 2005):

- Evaluation and development of improvements to existing baits, biomarkers, and vaccines and initiation of efforts toward new, more effective oral vaccines and baits is critical given apparent limitations of the only licensed vaccine in some species under field conditions
- A more comprehensive understanding of rabies reservoir species population structure and dynamics in relation to ORV strategies
- Reduced translocation of rabies reservoir species
- An applied understanding of the economic costs and benefits of ORV intervention
- Enhanced coordination on rabies control in North America
- Environmental compliance
- Conducting meaningful research to address existing data gaps
- Development and implementation of real-time surveillance tools (e.g., RabID)
- Development and implementation of rapid field diagnostics (e.g., dRIT)

New challenges will arise, emphasizing the critical niche that is filled by the Planning Team in charting future program direction. Many of these challenges will continue to underscore the need for collaboration among multiple disciplines, including cooperation among federal, state/provincial, tribal, county, and municipal agencies with differing missions and perspectives and paying attention to the spectrum of public attitudes toward wildlife and rabies control (Slate et al. 2002).

The cost of eliminating rabies in carnivores in North America will require strategic financial planning and resources. Funding increases for agencies and nongovernmental organizations are needed, but are not likely the complete remedy. It is essential to use the Plan's broad partnerships to reach out to other interests, integrating the needs of rabies control with other sociologically desired outcomes like reduced health care costs and the emotional stress due to the threat of rabies. In this way, rabies management funds can be leveraged with the millions of dollars expended annually for these issues. Plan partners can help shape future support for programs through the Plan's strong scientific foundation – specifically the ability to determine the type, amount, and location of actions required to achieve desired management objectives.

The challenge for the Plan community is threefold:

1. To direct available funds where they can be effectively applied
2. To capture the potential benefits of a host of rabies management-related federal, state/provincial, tribal, and local programs
3. To better inform those making management decisions by improving the scientific knowledge necessary to achieve Plan goals

To address these challenges, the Planning Team should:

- Strive to acquire resources to realize the Plan's visions and accomplish the recommendations in the Plan
- Foster appropriate links with other governmental and nongovernmental groups that affect wildlife disease spread or other issues in priority areas of North America and develop effective liaisons across related sectors of the economy
- Foster appropriate links with areas outside of North America that may be important to North American rabies control
- Recognize, monitor, and address emerging social, economic, and environmental trends that could affect target species and seek new cooperative opportunities for rabies management

Strive to Implement Cost-effective Plan of Actions

The economics of rabies generally has been viewed as a public health issue (Sterner and Smith 2006). However, researchers have identified a number of potential costs/savings related to rabies management that not only affect public health but other aspects of the environment as well. Sterner and Smith (2006) indicate that the benefits of rabies management are the savings, or future non-incurred costs, associated with potential human health, agriculture, veterinary, legal, and protected species losses. Therefore, benefits include all direct and indirect medical and nonmedical costs that would be avoided as a result of a proposed control program (Kemere et al. 2001). The costs/savings of rabies epizootics and rabies management vary by stage of the epizootic, geographical region, effectiveness of control, and thoroughness of measurement (Meltzer 1996, Sterner and Sun 2004, Sterner and Smith 2006).

Potential variables involved in costs/savings from managing wildlife rabies include: human PEP, pre-exposure prophylaxis, pet and livestock vaccinations, replacement of pets or livestock that have succumbed to rabies, quarantine of suspected rabid animals, adverse reaction to PEP, public health charges such as laboratory tests and investigation of cases, animal control costs for capture and removal of suspected infected animals, insured human death claims, and resource loss of rare and threatened mammals (Sterner and Smith 2006, Uhaa et al. 1992, Meltzer 1996, Sterner et al. 2004, Sterner and Sun 2004). Other indirect nonmedical costs such as time and wages lost due to PEP treatment, transportation costs involved in seeking PEP treatment, business losses due to decreased recreational activities in affected areas, public education regarding rabies, and the value of potential lost life, have also been used in analyzing the costs/savings of rabies management (Shwiff et al. 2007, Kemere et al. 2001). Research has documented that pet vaccinations and human PEP are two main cost factors that increase dramatically during wildlife rabies epizootics (Sterner and Smith 2006, Uhaa et al. 1992, Meltzer 1996, Sterner and Sun 2004).

A TVR program to control rabies in skunks and raccoons was implemented in Toronto in 1992 and cost an estimated \$450 to \$1,150 CAD/km² (Rosatte et al. 1992). A more recent cost estimate of \$500 CAD/km² for a TVR program in Ontario was presented by Rosatte et al. (2001). This analysis assumed the latest cost estimate in Rosatte et al. (2001) is the most applicable for comparing this alternative with ORV programs. At the exchange rate of 0.86 USD and 9.55 MXN per CAD (OANDA 2007), the cost would be about \$431 USD/km² or \$4,775 MXN/km².

In contrast, Kemere et al. (2001) estimated the cost of establishing an ORV barrier of 102,650 km² from Lake Erie to the Gulf Coast as totaling about \$135 USD/km² (costs included \$1.30 USD/bait, 75 baits/km², \$8.62 USD/km² for aerial distribution cost, and \$15 USD/km² for program evaluation) which equates to \$157 CAD/km² and \$1,495 MXN/km² (OANDA 2007). This is comparable to the reported cost of ORV in Ontario of \$193 CAD/km² (\$166 USD/km², \$1843 MXN/km²) (Rosatte et al. 2001). Broad focused analyses by Kemere et al. (2001) indicate that a large-scale ORV program should be economically feasible, given the program costs and avoided cost assumptions. Given that economics are central to rabies control, continuing analyses with greater sophistication are needed.

It appears a TVR program alternative to managing raccoon rabies could cost about three times as much as ORV, which could invoke the additional personnel complications associated with supervising and managing a large trapping force. Although a greater known proportion of targeted raccoon populations may be vaccinated by this approach (Rosatte et al. 2001), it is probably not necessary to achieve such greater vaccination rates because ORV programs have been successful in stopping or eliminating raccoon rabies outbreaks (USDA 2004).

Seek Multiple Sources of Funding to Meet Plan Goals

The largest cost due to wildlife rabies is the cost of vaccinating domestic animals, both large and small. Domestic animals may face multiple sources of wildlife rabies (Meltzer and Rupprecht 1998). Despite evidence that control of dog rabies through programs of animal vaccination and population control can reduce the incidence of human rabies, exposure to rabid dogs is still the cause of over 90% of human exposures to rabies and more than 99% of human deaths worldwide (CDC 2006). The cost of these programs prohibits their full implementation in much of the developing world, and in even the most prosperous countries the cost of an effective dog rabies control program is a drain on public health resources. The estimated annual expenditure for rabies prevention in the U.S. is over \$300 million, most of which is spent on dog vaccinations. An annual turnover of approximately 25% in the dog population necessitates revaccination of millions of animals each year, and reintroduction of rabies through transport of infected animals from outside a controlled area is always a possibility should control programs lapse. Reservoirs of wildlife rabies are also potential sources of rabies infection for dogs in Europe and North America (CDC 2006).

Advocacy for rabies prevention and control at national level

- Policymakers should be informed about the burden of rabies and the need for systematic and sustained control programs, sufficient resource allocation and resource mobilization, and coordination
- Senior-level managers in health, agriculture, and natural resources departments should identify and give adequate support to program officers at state/provincial, tribal, and local levels
- Private medical practitioners should be trained regarding wound treatment, and immunization choices and schedules
- Media, educators, local community leaders, and other influential groups should be mobilized to create awareness and promote community involvement in rabies control activities (WHO 2005)

Ensure Adequate Laboratory Support

The laboratory plays an important role in the epidemiological diagnosis, control, and monitoring of rabies. Adequate support to develop and sustain rabies laboratory capability and capacity in those laboratories that contribute to rabies control efforts is critical to sustain an affordable and successful program. Failure to provide accurate, sufficient, and uniform surveillance for the geographic distribution and prevalence of rabies virus in vector species, or the accurate identification of variants, will provide incorrect data and flawed assumptions in the making of rabies control resource decisions, leading to failure of control efforts; inefficient deployment or squandering of resources; appearance of failure that could end funding prematurely; and, potentially, human mortality.

National and regional contributing laboratories, as well as all state, provincial and local public health laboratories performing rabies testing, must be given adequate funding to ensure:

- Recruitment and retention of trained and experienced laboratorians
- Continued laboratory staff access to initial and periodic, uniform and skilled training
- Laboratory infrastructure, equipment, and reagents to adhere to standard protocols for the direct fluorescent antibody test and other applicable methods
- Resources for collection and proper transport of samples to laboratories
- Field staff trained and equipped to properly utilize emerging field testing strategies
- Establishing and supporting real-time and reliable data management tools
- Support for laboratory research and development to advance our knowledge of, and affordable methods for rabies virus detection, rabies variant characterization, rabies antibody assays, vaccine development, bait and biomarker development, and the epizootiology of terrestrial and chiropteran rabies
- proper biosecurity and biosafety measures for each facility according to its specific requirements, to the type of laboratory work conducted, and to local and geographical conditions
 - Laboratories should be developed exclusively for the goal of managing rabies
 - Appropriate laboratory design such as double access doors; smooth surfaces on walls, floors, ceilings, and countertops; and proper ventilation systems with air extractors and filters
 - Personal protective equipment
 - Vaccination for laboratory personnel and titer checks
 - Disposable equipment and sterilization chambers
 - Receptacles for infectious biological and medical waste and appropriate disposal mechanisms
 - Personnel and inventory protocols
 - All other necessary measures as established in Laboratory Biosecurity Guidance (WHO 2006).



Maintain and Expand Partnerships

The Plan will provide a concerted approach to rabies management and, therefore, will strive to optimize efficient use of existing cooperative initiatives, treaties, instruments, and mechanisms. The Plan will promote alliances and cooperation, and seek to elevate public awareness of rabies-related issues. The primary organizations that will be involved in the implementation of the Plan will include:

- National authorities (including local, state/provincial, tribal, and national governmental authorities)
- Nongovernmental organizations (at the local, national and international level)
- International organizations (WHO, PAHO)
- Indigenous and local communities (Navajo and Hopi tribes)
- Civil society
- Financial institutions
- Organizations and associations active in the economic sectors, and private enterprise
- Research and education community (research institutes, schools, universities, researchers and scientists)
- Information dissemination organizations and educational institutions

Develop Effective Liaisons among Participating Countries and across Various Sectors of Government and Other Interested Entities

To achieve rabies management goals, cooperation, coordination, and collaboration are required among Canada, U.S., and Mexico. Spillover of canine rabies, enzootic in Mexico, into coyotes and the subsequent outbreak in south TX in the 1990s; spread of rabies in red foxes into northern NY and New England as recently as the early 1990s; movement of the raccoon variant of rabies virus into southern Ontario in 1999; and the movement of raccoon rabies into eastern New Brunswick in 2000 are recent events that underscore the need for a viable North American Rabies Management Plan (Slate et al. 2005).

In most countries, several government agencies deal with rabies. Generally the Ministry/Department of Health is responsible for the prevention of rabies in humans; Ministry/Department of Agriculture is responsible for rabies management in domestic animals, and the Ministry/Department of Natural resources has responsibility for rabies related issues in wildlife. Other ministries/departments, such as commerce, industry, health services, agriculture, or science and technologies are involved in rabies vaccine production and imports, dog population management and pet immunization (WHO 2005). Nongovernmental organizations, universities, and animal welfare groups also have a stake in rabies control and often these groups act independently, in tandem, or at odds with one another. In Europe, the interaction and collaboration between the veterinary and public health departments is minimal or non-existent at all levels in many countries, resulting in an unproductive or underutilized use of resources. Establishing a central coordinating body or mechanism is necessary for ensuring that the efforts for rabies control are cohesive and give satisfactory results (WHO 2005).

Technical cooperation among countries should concern the following closely interrelated elements (WHO 2005):

- Rapid diagnosis and development of appropriate surveillance for immediate post-exposure prophylaxis in people and disease control in animals
- Antigenic and genetic typing of virus isolates to determine epidemiological patterns and the source of infection in cases occurring before, during and after vaccination campaigns
- Planning, implementing and evaluating local, regional, and national programs
- Promotion and coordination of control programs across borders in case of transboundary spread
- Human and animal vaccine procurement through imports and/or development and transfer of technologies for the production and control of modern safe and effective vaccines for use in animals and humans
- Provision of training or short-term expertise as required
- Enhanced advocacy of rabies to generate public awareness and political commitment for managing or possibly eliminating rabies
- Development of an ORV bank that could be drawn upon during shortages, national emergencies, or rabies outbreaks or breaches in barriers

To accomplish these elements, four major program components should be taken into account (WHO 2005):

1. The planning and management of local, county, state/provincial, tribal, regional, and national rabies control programs. Efforts should be made to fully incorporate and coordinate rabies control activities in all levels of the health services, aligning them with other public health programs such as the expanded program on immunization and those for tuberculosis and vector-borne diseases. In this manner, synergies between programs improve logistical use of human, material, and financial resources.
2. Cooperation with various institutions and the pharmaceutical industry in the provision of vaccines, including promotion of the transfer of technology for rabies vaccine production to developing countries, whenever feasible, and technical cooperation in program, planning and management to ensure proper vaccine delivery.
3. Promotion of funding by bilateral and multilateral agencies and other donor agencies within the framework of technical cooperation.
4. Coordination of international services in collaboration with both governmental and non-governmental organizations [i.e., Food and Agriculture Organization of the United Nations, the World Organization for Animal Health (OIE), World Society for the Protection of Animals (WSPA), and the International Association of Human–Animal Interaction Organizations (IAHAIO)].

Monitor and Address Emerging Social, Economic, and Environmental Trends that Affect the Management of Rabies

Several social, economic, and environmental trends are emerging across countries, cultures, and communities that have facilitated the resurfacing of previously controlled zoonoses or aided in the spread of existing zoonoses to new areas. These trends also have the potential to negatively impact how various zoonoses, such as the rabies virus, are managed. Chomel (2007) identifies modifications to natural habitats and human behaviors as the leading causes of the resurfacing or spread of zoonotic infectious diseases. Such emerging social, economic, and environmental trends include but are not limited to the following, several of which are discussed below:

- Expansion of human populations
- Encroachment on wildlife habitat
- Changes in agricultural practices
- Globalization
- Wildlife trade
- Ownership/Import of exotic pets
- Importing adopted domestic animals
- Consumption of exotic foods
- Live animal and bushmeat markets
- Translocation/relocation
- Access to petting zoos
- Nuisance wildlife control
- Wildlife rehabilitation
- Animal rights and animal welfare issues
- Development of ecotourism
- Internet issues
- Wildland/urban interface issues
- Changing demographics
- Organic farming
- Climate Change



The wildlife trade has grown over the past decade, partly fueled by the increased popularity of exotic pets (Kuehn 2004). The legal international wildlife trade is estimated to be a \$6 – \$10 billion USD industry (Chomel 2007, Kuehn 2004). The illegal trade in wildlife is also estimated to be a multi-billion dollar industry (Kuehn 2004). The wildlife trade, whether legal or illegal, provides mechanisms for disease transmission that can cause human disease outbreaks and also threaten livestock, international trade, native wildlife populations, and ecosystem health (Chomel 2007). The Internet has helped fuel the trade in captive wildlife as it has allowed potential pet owners easy access for browsing through a range of available wildlife including kinkajous, prairie dogs, armadillos, and marmosets (Kuehn 2004). The monkeypox outbreak in the U.S. brought national attention

to trade in captive wildlife pets. It also highlighted the practical and ethical challenges facing animal and public health professionals who must treat the captive wildlife pets (Kuehn 2004) and the people who become infected as a result. The National Association of State Public Health Veterinarians (NASPHV) believes that the best way to prevent exotic disease transmission is to prevent species likely to transmit these diseases from entering the country and the pet trade. NASPHV and the Council of State and Territorial Epidemiologists (CSTE) in the U.S. have urged government agencies to enact a more comprehensive ban on exotic and native wildlife imports and exports that may negatively impact public health, and to more closely monitor interstate movement of native and exotic wildlife (Kuehn 2004). Furthermore, education, including highlighting past zoonotic disease transmission to humans, has proven successful in discouraging ownership of certain species (Kuehn 2004, Chomel 2007).

Not only are animal and public health agencies faced with increased opportunities for disease transmission as a result of trade in exotic and native species, but also from relocation or translocation of free-ranging wildlife (USDA 2000). Relocation often results in disease transmission from the introduced animals to the resident population. A well known example in the U.S. involved the introduction of rabies into the mid-Atlantic region in the 1970s when hunting pens were repopulated with raccoons trapped in rabies-endemic zones of the southern U.S. (Chomel 2007). While any single relocation has the potential to transmit disease from one area to another, documentation of disease-related aspects of relocation occurs infrequently (USDA 2000). A study conducted to review potential disease transmission as a result of relocation found that animals in nearly 25% of relocations were not given a physical examination by a biologist or veterinarian prior to release. Better preparation, involving risk assessments, pre-movement testing, and collaboration between animal health agencies, would aid in decreasing disease transmission during animal relocations (USDA 2000).

The increasing number of wildlife rehabilitators and nuisance wildlife control operators also contributes to the issue of disease transmission and can have a negative impact on the ability to effectively manage zoonotic outbreaks. In the state of Michigan alone, there are approximately 275 licensed wildlife rehabilitators and 400 licensed nuisance wildlife control businesses (DNR 1999). These groups often relocate captured wildlife even if humane euthanasia is biologically the most appropriate option. Although social issues concerning wildlife (i.e., animal welfare, animal rights) are often not as important for nuisance wildlife control operators as for rehabilitators, their clientele often insist on relocation over euthanasia. Regulations vary between states and provinces regarding the issue of wildlife relocation. Where relocation is allowed, the distance in which licensed wildlife rehabilitators and nuisance wildlife control operators may transport and release captured wildlife may not be indicated (DNR 1999). More stringent legislation needs to be developed regarding the relocation of wildlife, especially for those species with greatest risk of transmitting disease.

Petting zoos, where children are allowed to approach and feed captive wildlife and domestic animals, have also been linked to several zoonotic disease outbreaks. Chomel (2007) indicates that more than 25 outbreaks of human infectious diseases have been associated with visitors to petting zoos between 1990 and 2000 (Chomel 2007).

Animal exhibitors may also play a role in disease transmission, not only through movement of animals, but also by selling to captive exotic animal owners. The American Zoo and Aquarium Association documented that more than 1,000 mammals are sold, donated, or traded to dealers and brokers each year by affiliated zoos. Surplus animals may end up at auction markets, in hunting preserves, or in the pet trade (USDA 2000).

Chomel (2007) points to an emerging social trend, adventure travel, as another source for disease transmission. Chomel (2007) identifies adventure travel as the largest growing segment of the leisure travel industry, with a 10% per year growth rate since 1985. Adventure travel, which includes safaris, tours, sports, and extreme travel, increases the risk that participating tourists will contact pathogens uncommon in industrialized countries (Chomel 2007). Another trend that has heightened the risk for zoonotic disease spread and raised major public health concerns has been the considerable increase in bushmeat consumption in many parts of the world (Chomel 2007). As a result, live animal markets, which were quite uncommon in North America until recently, have emerged as a new type of commercialization within specific ethnic groups as product freshness is assured (Chomel 2007). Key measures for reducing transmission of zoonoses include proper education of tourists about the risks of outdoor activities and better control of the live animal trade, including sales to bushmeat markets (Chomel 2007).

Two environmental trends, urbanization and land-use change, are on the rise in many parts of the world. These trends are creating changes in environmental conditions along urban-rural interfaces which are, in turn, creating new ecological and societal challenges and opportunities (Macie 2003). Public attitudes, values, and perceptions vary along a gradient that extends from the city center out toward rural areas. As more urbanites move to the urban fringe and as the landscape transitions from rural to urban land uses, a shift in the public's value system can be observed (Macie 2003). Because of differing values along this gradient, conflicts emerge over the area's natural resources and how the land should be used. Land use planning, policy, economics, social dimensions, and demographics must all be taken into consideration in order to effectively resolve interface issues (Macie 2003). These measures can greatly influence the availability, management, health, and condition of natural resources in the area. Land use change and the impact of urbanization affect quality-of-life measures such as air and water quality, opportunities for outdoor recreation, risk of catastrophic wildfire and flooding, and threats to human health and safety (Macie 2003). As a result of the emerging trend toward urbanization and changing land uses, potential interface issues must be addressed during land use planning and policy-making to facilitate the management of infectious wildlife diseases such as the rabies virus. Conservation of habitat biodiversity is also critical for preventing the emergence of new reservoirs or amplifier species (Chomel 2007).

In this era of increasing technology, the Internet has become one of the most consulted sources of information (Vedder 2001). This emerging social and technological trend has contributed to the increased difficulty in effectively managing wildlife diseases. The ease with which information is accessible and can be dispersed, facilitates the ability to mislead the audience, either intentionally or unintentionally (Vedder 2001). Amid all the excellent free information that is available online, there are many false assertions and misleading arguments. Distinguishing reliable from unreliable sources of information is especially

difficult in an online context (Levine 2005). For instance, typing the word “rabies” into a search engine such as Google™ pulls up a host of sites that discuss the rabies virus. It is then up to the user to separate fact from fiction, half-truths, or misleading information and determine which sites to trust for reliable information. Levine (2005) identifies education as only part of the solution when it comes utilizing the Internet as an information source and states that a more effective approach is for governments to fund and promote reliable web portals.

These and other emerging trends signify new challenges for animal and public health agencies (USDA 2000). An estimated 75% of emerging infectious diseases are zoonotic, mainly of viral origin, and are likely to be vectorborne. Major public health events, such as the emergence and rapid spread of the West Nile virus in North America and the monkeypox outbreak in pet prairie dogs in the U.S., have awakened communities to the threat of zoonotic infectious diseases and underscored the need for closer collaboration between the veterinary profession, wildlife specialists, and public health officials (Chomel 2007). These events have emphasized the need for early detection, ongoing surveillance, control, and prevention of zoonoses (Chomel 2007). As suggested by Kuiken et al. (*in* Chomel 2007), it is time to form “a joint expert working group to design and implement a global animal surveillance system for zoonotic pathogens that gives early warning of pathogen emergence, is closely integrated to public health surveillance and provides opportunities to control such pathogens before they can affect human health, food supply, economics or biodiversity.” Major tasks that should be taken by the international community include better integration and coordination of national surveillance systems in industrialized and developing countries; improved reporting systems and information sharing; active surveillance at the urban-rural and urban-wildland interfaces; training of professionals, such as veterinarians and biologists, in wildlife health management; and establishment of collaborative multidisciplinary teams that are prepared to respond during outbreaks (Chomel 2007).

Continue to Review Plan Accomplishments and Address Deficiencies

Measuring performance is a critical element to successful implementation of projects. To ensure that the Plan is fulfilling its purpose, the Planning Team will undertake a cooperative and comprehensive assessment of progress toward Plan goals. This process will help determine the effectiveness and efficiency of the selected actions, assist in setting priorities, demonstrate the impact of projects, and ultimately improve the effectiveness of the Plan, the delivery mechanisms being used, and the roles and functions of the Planning Team and stakeholders/joint ventures. Monitoring and evaluation of performance are essential components of the strategy. Positive changes in environmental conditions often take decades to become visible, and a great number of organizations and individuals are needed to successfully implement rabies control and elimination measures and detect links between management decisions and results. Targets and indicators of achievement need to be clearly defined and agreed upon for each project. The monitoring and evaluation process must be jointly designed to provide meaningful information to the Planning Team, stakeholders, and the public on progress made towards achieving established goals. The evaluation process will be accomplished through a 5-year program evaluation. The results of the evaluation will guide future program developments in effectively managing rabies in North America.

The 5-year assessment will include a review and potential update of national objectives based on evaluation results, identification of additional research needs, and a refined estimate of the resources needed to accomplish Plan objectives. The assessment will also solidify strategic biological planning, implementation, and evaluation throughout the Plan community, and renew the working relationships between the Planning Team and stakeholders/joint ventures. It is vital that all the major Plan stakeholders participate in the review process. The Planning Team will provide international leadership in this endeavor.

VIII. Looking Forward

Vision for the Future

The establishment of a North American Rabies Management Plan represents a key step in facilitating planning processes by which mutual goals and objectives can be identified and met among Canada, Mexico, and the U.S. This Plan allows for enhanced international cooperation, coordination, and collaboration among countries with common borders and is essential for attaining the rabies management goals of containment and regional elimination of specific rabies virus variants (Slate et al. 2005).

Containment and elimination of terrestrial rabies in wildlife is a daunting, multifaceted task, requiring the integration of enhanced rabies surveillance, oral rabies vaccination, a range of contingency support approaches, effective post-vaccination evaluation procedures, economic and ecologic decision indicators, and other factors into a comprehensive rabies management strategy. To achieve success, expertise from several disciplines including wildlife management, veterinary and human medicine, economics, and others must be brought together in order to solve such complex, integrated programs of scale (Slate 2005).

All three countries are moving towards greater involvement of stakeholders, increased information sharing across borders, and have been involved with research, planning, and direct actions for managing rabies. Despite these remarkable precedents in the rabies management field, greater accomplishments are possible through trilateral cooperation. Through this Plan, mutually beneficial goals can be identified and priorities may be set for reaching these goals. Strategies can in turn be collaboratively formulated and implemented for the enhanced protection of humans, pets, domestic animals, and natural resources.

Several priorities have been identified for rabies management programs in Canada, U.S., and Mexico to succeed and include: improved or new oral vaccines and/or baits to reach target species; optimized ORV strategies; effective communication; strategies to limit translocation and population growth; and access to sufficient long-term funding. These key priorities must be addressed to ensure that rabies management has the optimal chance of achieving long range programmatic goals of eliminating specific variants of rabies virus in North American terrestrial carnivores (Slate et al. 2005).

Partners in the North American Rabies Management Plan are on a path for success in effectively managing and eventually eliminating terrestrial rabies virus variants in Canada, Mexico, and the U.S. The adaptive processes advocated in this Plan offer a clear path to success, even in the face of ecological and sociological uncertainties.

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