THE ROLE OF WILDLIFE IN HUMAN AND ANIMAL DISEASE

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Abstract: Strategies to assess and reduce risk associated with disease agents in wild animals must be based upon thorough knowledge of the epidemiology of the disease agent, specific local information, and other factors. Risk evaluation and management efforts will involve organizations with differing expertise and cooperation will be essential between wildlife management, public health, and domestic animal health agencies. Risk reduction strategies may be based upon manipulation of the disease agent, the host, the environment, and/or human activities. Management of human activity, particularly the promotion of biosecurity, may be the most efficient strategy because other measures are more difficult and expensive. The science of risk assessment and disease management in wildlife is growing and evolving as new situations arise and as new methods are developed to meet the needs of wildlife resource, animal agriculture and public health interest groups.

Key words: disease management, epidemiology, epizootiology, risk assessment, wildlife disease

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INTRODUCTION

The occurrence of disease agents in free-ranging wildlife may present a risk to the health of domestic animals and human beings as well as to the wild animals. This report provides information regarding the assessment and reduction of risk associated with disease agents in wildlife and includes some examples of disease interactions between wildlife, humans, and domestic animals. This article covers only free-ranging wild birds and mammals and does not include captive or domesticated wildlife or zoo animals.

ASSESSMENT OF DISEASE AGENTS IN WILDLIFE

Many infectious agents that cause disease in livestock, poultry, or human beings occur in selected species of wild birds or mammals. In general, wild animals are susceptible to infection by the same bacteria, viruses, and parasites that infect domesticated animals. Disease transmission can occur in either direction and disease relationships between wild and domestic animals should be viewed as a two-way street. However, there often are differences in the response of wild animals to infection as well as great variation in the potential role that wildlife may play in the epidemiology of these disease agents in humans, livestock, and poultry. Wild animals can represent a true risk factor, or they may harbor significant pathogens while posing little or no threat to other species. The magnitude of risk must be evaluated in order to determine whether it is necessary or worthwhile to

develop and implement risk reduction strategies.

Once a significant infectious agent has been identified in wildlife, strategies to assess and reduce any associated risk must be based upon many factors including the epidemiology of the disease in wildlife, humans, and domestic animals. Of particular importance are interactions between livestock, poultry, or human beings and the wild animals in which the disease agent is present, as well as the biology of these animals. Many risk reduction strategies are based on eliminating or minimizing these interactions because control of infectious disease agents in free-ranging wildlife may be expensive and difficult or impossible. Thus, collection of all of the appropriate information is essential in determining the necessity, feasibility, and affordability of strategies to reduce risk.

Although scientific literature is an excellent source of information regarding general aspects of disease agents, their hosts, and potential control methods, knowledge of the local situation is essential. Important local information will include the density and distribution of wildlife species important in the epidemiology of the disease and the prevalence of the disease agent in these animals. Knowledge regarding the numbers, distribution, husbandry, and status of the disease agent in domestic animals in the area also is essential. Additionally, information is needed regarding disease incidence and wildlife interactions among local human populations. Because information must come from a variety of agencies with differing expertise and these agencies may be involved in potential risk reduction strategies, cooperation will be essential between several organizations, particularly public health, animal health, and wildlife management agencies. It also should be noted that collection of additional data during management operations is necessary to modify current strategies to maximize efficacy and to plan future disease control programs.

Surveillance for disease agents in livestock and poultry generally is conducted by the animal health regulatory agency within a country through a variety of methods including morbidity and mortality investigations, abattoir surveys, serological surveys, and disease testing within eradication programs. Similarly, governmental public health agencies assemble information regarding disease incidence in human populations. However, authority, funding, and responsibility for wildlife disease investigation and reporting are not well defined in many countries (Bengis et al. 2002). Because resources are limited for wildlife disease work, surveillance must be based on interagency cooperation and structured to maximize information gained from carcasses, captured animals, or other sources.

In addition to the authority issues, the actual detection of disease agents in wildlife can be very difficult because of the wild nature of free-ranging animals and other factors. Disease outbreaks among wildlife may be missed or their detection may be delayed because wild animal carcasses frequently are recycled into the environment before they can be found and examined. Live wild animals generally are intractable, the capture of the majority of the animals in a population often is impossible, and re-capture of suspect animals for follow-up testing is unlikely. Furthermore, restraint may lead to the immediate or eventual death of the animal or induce physiologic changes that alter results of diagnostic procedures (Thorne et al. 2000).

Other difficulties are encountered when standard diagnostic tests are applied to wild species. Diagnostic protocols in which the causative organism is observed or isolated should have similar sensitivities for

most wild or domestic species. However, problems may be encountered with the use of serological or other *in vitro* tests that were developed for domestic species. Many of these tests have not been validated in wildlife and there may be significant differences in test sensitivity and specificity when used in non-domestic animals, as well as idiosyncratic reactions in some species. Some of these tests, such as the fluorescent antibody test for rabies, can be considered valid in individual animals, while others must be regarded as valid only in the context of whole herd testing, such as intradermal tuberculin or blood-based gamma interferon tests for mycobacteriosis (Bengis et al. 2002).

RISK REDUCTION STRATEGIES FOR DISEASE AGENTS IN WILD ANIMALS

When a disease agent in wildlife presents significant risk and feasibility studies indicate potential success, management strategies should be considered. Although this report deals with managing risks to domestic animals and human beings, it should be recognized that certain diseases might be managed to reduce impacts on highly valued wildlife populations. In some instances, wild animals may harbor a disease that has been eradicated or nearly eradicated from domestic animals, as is the case with bovine tuberculosis and brucellosis in wild ruminants and Aujeszkey's disease in feral swine in the United States. Regardless of the reason for management of the disease, the methods of control often are the same and they may be limited.

Wildlife disease management strategies are based upon manipulation of the disease agent, the host, the environment, and/or human activities (Wobeser 1994). Controlling the disease agent or its vector is the most direct strategy but often is very difficult due to lack of appropriate strategies. Host population management strategies offer more options and include restrictions on distribution, removal of infected or exposed animals to reduce the source of the disease agent, and reduction of population density to decrease opportunities for transmission. Many disease control plans are based on management of population density because wildlife resource authorities are experienced in this field. However, the success of such strategies will be greatly influenced by disease and host-specific factors. Although reduction of population density more often is intended to reduce disease transmission, total depopulation may be attempted in order to eliminate a disease. The difficulty and expense of wildlife depopulation may reduce efficacy and efforts may be hindered by public opinion against such a strategy. It should be noted that modifying public opinion through education and information often is necessary to improve acceptance of any disease management strategies in wild animals (Wobeser 1994).

Treatment or vaccination of wildlife may be practiced to manage diseases under certain circumstances; however, treatment, vaccines, and delivery systems developed for domestic animals may not be safe, effective, or suitable for wild animals. Treatment rarely is attempted, but occasionally has been used for individuals or small populations of species of critical concern. Immunization of wild animals may have greater utility under appropriate conditions, but requires safe and effective vaccines and delivery systems. Consequently, this is a growing area of interest and activity in the laboratory and the field. Examples include successful oral rabies vaccination programs in wild carnivores at selected locations in Europe and North America (Rupprecht et al. 2001), and developing oral vaccine strategies to

control classical swine fever in wild boars (*Sus scrofa*) in parts of Europe (Artois et al. 2002). Additionally, wild elk (*Cervus elaphus*) in the Greater Yellowstone Area of the United States are being immunized against *Brucella abortus* with a product introduced by a projectile fired from a gun (Thorne et al. 2000).

Wildlife and land managers may modify environmental and habitat conditions to manage diseases in wild animals. These strategies typically are used to reduce survival of specific disease agents or vectors, lower population densities and reduce transmission rates, or make areas unattractive to wildlife species. Habitat modifications usually do not produce rapid results, but the effects generally are long lasting (Wobeser 1994).

Because managing diseases via manipulation of the disease agent, host, or environment are the most difficult and expensive strategies, management of human activity may offer the best opportunity for success. Restrictions on translocation and re-introduction of free-ranging, captive, or domestic animals should be designed to prevent the introduction of disease. Because disease control is so difficult in wild animals, prevention of disease introduction always should be a primary consideration.

Management strategies also should address public practices that influence wildlife population density and behavior. For example, extensive supplemental feeding or baiting of wildlife may artificially inflate populations and cause gatherings of large numbers of animals thus increasing opportunities for disease transmission. Examples in the United States include establishment of bovine tuberculosis in wild white-tailed deer (*Odocoileus virginianus*) in Michigan (Schmitt et al. 1997), where large-scale supplemental feeding and baiting were practiced, and the rapid spread of *Mycoplasma gallisepticum* associated with conjunctivitis in wild finches common at backyard bird feeding stations (Fischer et al. 1997).

In many instances, it may be impossible to manage diseases in wild animals. In these cases, reduction of risk to other species must be based on protection of humans or domestic animals by partitioning them from wild animals to reduce exposure or by taking other protective measures such as immunization of persons or domestic animals. The presence of disease agents in wildlife may potentially preclude raising of certain livestock or poultry species in some areas. However, with thorough knowledge of the epidemiology of a disease, it may be quite practical to construct effective physical barriers, such as fences or housing, to protect domestic animals. In other cases, animal husbandry practices may be based on the behavior of the wildlife in order to prevent contact between wild and domestic animals. Education of the public will be key components of risk reduction strategies, as will human compliance with recommendations and regulations. Livestock and poultry producers must have adequate scientific information to provide biosecurity for their animals and laypersons must be educated regarding the risk of diseases in wild animals and measures that should be taken to prevent them.

Combinations of the above strategies often are employed to reduce disease risks associated with wild animals. Those strategies that are technologically and financially achievable should be used when diseases pose a significant risk to wildlife, domestic animals, and/or human beings. Strategies that reduce the possibility of transmission of disease agents from wildlife to other species often are more practical than actual management of the disease in wild animals. In some instances, it may be possible to thoroughly exclude a disease agent from domestic animals, despite its

presence in wildlife. This concept, known as "compartmentalization," may be used in determination of the trade status of countries when disease agents occur in wildlife without risk of transmission to livestock or poultry. These determinations will be highly dependent upon thorough knowledge of the epidemiology of the disease, as well as demonstration of the efficacy of the risk reduction measures.

The following are examples of selected disease problems associated with wildlife and the measures being taken to reduce risks to protect domestic animals and human beings. The complexity of disease control in wildlife is evident in these cases.

RABIES

Historically, rabies virus has been associated with domestic animals. However, widespread immunization of domestic animals in Europe and North America resulted in the emergence of wildlife as the most significant risk factor for rabies in humans, pet animals, and livestock. By 1960, rabies was found more frequently in wildlife than in domesticated animals in the United States, and wild animals accounted for 93% of the 7,369 non-human rabies cases in 2000 (Krebs et al. 2001). Thousands of raccoons (*Procyon lotor*) have been affected in a rabies epizootic that began in the Mid-Atlantic states in the late 1970s and has spread westward to Ohio and as far north as Canada (Krebs et al. 2001). Significant costs have been associated with surveillance and post-exposure treatment for rabies in the eastern states since the epizootic began. Currently in North America, genetically distinguishable strains of rabies virus are associated with individual carnivorous species such as red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), arctic fox (Alopex lagopus), raccoon, striped skunk (*Mephitis mephitis*), bats, and other species. Nearly all of the human cases of rabies diagnosed in the United States since 1990 have been caused by viral strains associated with bats (Krebs et al. 2000).

Rabies occurs in domestic animals, wild carnivores, and bats in other American countries, and hematophagenous bats are significant in the epidemiology of disease in some areas. Domestic animals still account for large numbers of rabies cases in areas where widespread vaccination has not occurred. In Mexico, 94% of the 560 cases of non-human rabies cases reported in 2000 occurred in domestic animals with dogs representing 44% of all cases. However, there were 5 human cases of rabies in humans in 2000, which were all due to exposure to wild animals (Krebs et al. 2001).

In Western Europe, the red fox is the species most frequently associated with rabies while the arctic fox also plays a role in the epidemiology of the disease. Between 1977 and 1996, 77% of all rabies cases in wild or domestic animals were documented in red foxes (Rupprecht et al. 2001). Rabies also is found in bats and the number of bat rabies cases in Europe increased significantly between 1985-1990 (Brass 1994).

Rabies is significant because it is one of the few diseases in which vaccination of wildlife is a significant component of the disease control program in some regions. Oral rabies vaccination (ORV) of wildlife began with limited field trials in Europe as early as 1978. Since 1978, approximately 110 million baits containing a recombinant rabies vaccine have been distributed over approximately 6 million km^2 in Europe (Rupprecht et al. 2001). Between 1989 and 1994, the incidence of non-human rabies cases was reduced to less than 20 percent of the 1989 level in countries that had been conducting oral immunization campaigns prior to 1993 (Stoehr and Meslin 1996).

Some fox populations have increased in Europe apparently due to the ORV campaigns with hunters in Switzerland taking more than 3 times as many foxes in 1995 than in 1981 (Stoehr and Meslin 1996). Thus, control programs to reduce the risk of disease associated with wild animals may have significant population impacts on wildlife.

Oral rabies vaccination programs have been conducted in different wildlife species in parts of North America. In Canada, ORV has been successful in controlling red fox rabies in southern Ontario (Rosatte et al. 1993). In the United States, ORV has been used in coyotes (*Canis latrans*) in southern Texas. From 1988-1995, more than 500 cases of rabies had been diagnosed in the area, primarily in coyotes and dogs (Meehan 1995). However, the incidence of rabies in the area and the spread of the disease in Texas have markedly decreased since the control program began (Fearneyhough et al. 1998). Currently, ORV trials to control raccoon rabies are underway in parts of Massachusetts, New York, Ohio, Florida, Vermont, and New Jersey (Rupprecht et al. 2001).

Despite the success of ORV in various wildlife species in several locations, there are limitations to such programs. The programs are expensive, requiring much human effort and equipment, vaccine, bait, and other materials over a period of several years. For example, the total cost of oral rabies vaccine in Ohio between 1997 and 2000 was $102/km^2 to $261/km^2 (Foroutan et al. 2002). An area of nearly 33,000 km^2 was treated and the total cost of the 4-year program was approximately $5,125,000. An additional problem is the lack of suitable vaccines for some species significantly involved in the epidemiology of rabies. For example, skunks appear to be refractory to the recombinant rabies vaccines that have been successful in foxes, raccoons, and coyotes (Rupprecht et al. 2001). Moreover, vaccine and delivery systems are unavailable for bats that represent the primary risk factor for human rabies in the United States.

BOVINE TUBERCULOSIS

Since 1994, Michigan in the United States has recognized a problem with bovine tuberculosis (TB) in free-ranging white-tailed deer in a portion of the state (Schmitt et al. 1997). *Mycobacterium bovis* has been found in 449 of more than 105,000 free-ranging deer examined since 1995. *Mycobacterium bovis* has been found in other wildlife species, including elk, coyote, raccoon, opossum (*Didelphis virginiana*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), and red fox (Schmitt 2002). Most of these additional infected wild animals did not have clinical signs or lesions of bovine TB when examined. Since 1998, bovine TB has been found in 29 herds of beef and dairy cattle in the same area of the state. Consequently, Michigan lost its TB-free status for cattle and bison. Molecular epidemiology revealed that the same strain of *M. bovis* is occurring in all affected wild and domestic species thus indicating white-tailed deer are serving as a bovine TB reservoir for domestic cattle and free-ranging wildlife.

Prior to this situation, self-sustaining bovine TB had not been observed in a free-ranging cervid population in North America. Consequently, there are no existing control programs for bovine TB in wild deer, and there is much about TB in deer that is unknown. Since the recognition of the Michigan problem, an apparently endemic focus of bovine TB has been found in free-ranging wapiti in or near Riding Mountain National Park in Manitoba, Canada (Luterbach 2001). Unfortunately, bovine TB also is a well-known wildlife health

problem in other countries including South Africa where it is endemic in buffalo (*Syncerus caffer*) and has spilled over to other species including African lion (*Felis leo*) (Bengis et al. 2002).

In Michigan, it is believed that high deer densities and crowding of deer caused by supplemental feeding and baiting (hunting deer over feed) are the factors most likely responsible for the establishment of self-sustaining bovine TB in wild deer (Schmitt et al. 1997). By repeatedly bringing deer into close contact with each other, baiting and feeding enhance bovine TB transmission via inhalation of infectious aerosols and ingestion of bovine TB-contaminated feed (Whipple and Palmer 2000).

A multi-agency committee recommended a TB control plan that included reducing the deer density through legal hunting in the affected area, surveying wildlife populations, eliminating feeding and baiting of deer, banning the transport of free-ranging deer from the area, testing and removal of affected livestock, and educating the public. Since 1998, deer population densities in the area have been reduced by approximately 50% through hunting. Extensive surveillance has been conducted to identify areas that will need intensified management practices and to monitor progress of management strategies. Stringent restrictions have been imposed on supplemental feeding and baiting of deer in Michigan and public education programs have emphasized the need to control this disease in wildlife and livestock (Schmitt 2002).

Eradication of bovine TB from free-ranging deer will be difficult to accomplish and will require cooperation and collaboration of state and federal animal health and wildlife resource agencies. Animal health agencies do not have sufficient expertise in wildlife biology and management techniques to address the situation independently, while the same can be said for wildlife resource agencies faced with disease issues. Therefore, multiple agencies must rely on each other and work collaboratively to deal with the control of disease in wildlife; unilateral efforts cannot be expected to succeed (Thorne et al. 2000).

WEST NILE VIRUS

Historically, West Nile Virus (WNV) has occurred in sporadic epidemics throughout Africa, the Middle East, and western Asia (Marfin and Gubler 2001). However, WNV recently has emerged as a significant threat to human, domestic animal, and wildlife health in parts of Europe and North America. The transmission cycle of WNV typically involves wild birds and mosquitoes. Mosquitoes carry the virus in salivary glands and infect susceptible birds while acquiring a blood meal (Komar 2000). Wild birds serve as the amplifying host and reservoir for the virus. Aberrant hosts such as humans and horses usually become infected due to increased mosquito vector abundance in areas of viral activity (Hubalek 2000). Vector abundance may be directly related to climatic changes such as flooding. The primary mosquito species and vertebrate hosts in WNV epidemiology vary with geographical regions.

Although several well-documented WNV outbreaks have been reported in the Old World, the first outbreak of WNV in the United States occurred in 1999 in New York City and surrounding counties. Over an eight-week period starting in August 1999, there were 59 humans hospitalized with severe neurologic illness and seven deaths due to WNV. Simultaneously, an epizootic occurred in four states involving American crows (*Corvus brachyrhynchos*) and other avian species (Marfin and Gubler 2001). In 2000, WNV was found in 12 states and the

District of Columbia and through 2002, WNV had reached the west coast and several Canadian provinces. Through 2001, 14 human deaths had been attributed to WNV, but 274 fatal cases occurred in 2002 alone. During the same time, thousands of wild birds have been killed by WNV. To date, WNV has been found in more than 120 avian species in North America .

Wild birds played a critical role in the diagnosis of WNV as the cause of the human encephalitis outbreak in New York in 1999 (Eidson et al. 2001). Although another arbovirus initially was suspected, the fatal outbreak of encephalitis in wild birds occurring simultaneously with the human outbreak suggested a different etiology. Since then, surveillance of wild birds has proven to be a strong indicator of WNV activity in an area. The early detection of WNV in dead wild birds allows public health authorities to inform and educate the citizens regarding the risk factors for WNV and to evaluate the merits of mosquito control (Eidson et al. 2001).

It is not possible to control WNV in wild birds or to otherwise control wild birds to minimize the risk of WNV to humans, horses, or other domestic animals. Mosquito control has been of questionable value and public opinion in some areas has been against introduction of pesticides into the environment. Consequently, risks to humans have been reduced primarily through public education to prevent mosquito exposure with protective clothing, insect repellants, and staying indoors during hours of high mosquito activity. A vaccine has been developed and licensed for use in horses in areas where WNV has been documented.

AVIAN INFLUENZA AND NEWCASTLE DISEASE

Two major viral diseases of poultry, Newcastle disease and avian influenza, have wild birds as part of their epidemiology (Nettles and Fischer 2000). Both viruses behave similarly by having multiple strains that vary in host preference and pathogenicity. It is not uncommon to isolate these viruses from wild birds, but most of the viruses recovered are not serious threats to poultry. Wild birds have and always will harbor the building blocks of genetic material that could result in emergence of pathogenic strains of Newcastle disease and avian influenza; however, to blame wild birds for every new outbreak of these diseases is poor science. Many other birds, including backyard poultry and pet birds, are involved in the epidemiology of avian influenza and Newcastle disease. Species of *Mycoplasma* (Fischer et al. 1997) and *Salmonella* (Kirk et al. 2002) have been isolated from wild birds, but generally wild birds are not harboring the major pathogenic species or strains that affect poultry.

Because of the universal presence of wild birds and the potential occurrence of Newcastle disease or avian influenza viruses or other pathogens among them, the best way to reduce disease risk from wildlife is for poultry producers to partition their flocks from nature. Modern poultry producers recognize this fact, and intensive poultry confinement results in this effect. Vaccination, removal of menagerie birds, and wildlife habitat manipulation also may be employed (Nettles and Fischer 2000).

CONCLUSION

The examples cited above provide abundant evidence of the variety of strategies and the complexity of controlling disease risks associated with wild animals. Disease control programs require significant investments in determination of the risk as well as the actual control of the disease agents in wildlife. In addition to the financial and technological restraints inherent in such programs, public opinion

may hinder efforts, especially when control measures involve population reduction of popular wildlife species. The only hope for success of wildlife disease control efforts lies in cooperation between multiple agencies and interest groups, development and validation of methods for risk assessment and disease control, and education of the public regarding the need for such programs. The field of wildlife disease control is growing and evolving as new situations arise and as new methods are developed to meet the needs of animal agriculture, public health, and wildlife resource interest groups.

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