Management and Intervention

in

Diseases of Wild Animals

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Management and intervention in diseases of wildlife

Introduction (G. Wobeser)

What I want to do in a very concise way is to introduce some general ideas and concepts that we will return to and build on during the remainder of the course. These ideas include:

- a brief discussion of the nature of disease
- a look at the way disease affects the individual animal
- the interaction of other factors with disease
- an introduction to the way infectious diseases behave within animal populations.

<u>What is disease??</u>

Since we will be dealing with disease for the next few days we need to have some sort of definition. Often when we think of disease in wild animals, the vision that comes to mind is a large pile of dead bodies. Obviously, this may represent the outcome of disease but if we stop for a moment and consider disease in humans, we will realize that we use a different definition when we deal with our own species. Clearly, one doesn't have to be dead to be thought of as having a disease, e.g., "*heart disease*", "*gum disease*". Similarly, when veterinarians discuss disease in domestic animals, they often deal with "*production diseases*" that seldom if ever kill an animal but which impair productivity. When we discuss disease in wild animals, we need to be conscious that disease can have many sublethal and, in some cases even sub-clinical effects, that may have important impacts on the animals. For example, some diseases alter reproductive success, depress growth, suppress immune function, or alter behaviour, in ways that have serious population effects, but never directly cause the death of any animal.

> Disease includes any impairment that interferes with or modifies the performance of normal functions.

The things I like about this definition are that (a) it doesn't specify the type of cause that results in disease (so that we can include conditions resulting from genetic errors, trauma, chemicals, etc, as well as the more classical disease agents such as viruses, bacteria and parasites); and (b) it doesn't proscribe the degree of injury, so that a condition characterized by some loss of reproductive function is just as much a disease as one that kills hundreds of birds overnight.

> Disease ranges from subtle loss of function to total loss of function (death)

One of the major problems in understanding the effect of different types of disease on the individual animal is the lack of a "*currency*" for measuring the impact. For instance, how can we compare the effect of arthritis, that impairs one function (mobility), with the effect of a viral infection that results in a high fever? In economics, many different subjects can be compared by converting the value of different things to a common scale, money. When considering the ecology of disease, we can use energy as a currency to measure effect..

In the individual animal, expenditure or use of energy is balanced precisely with the energy available (assimilated and stored), and energy usage is divided among maintenance (respiration, normal movement, thermoregulation, defenses), production (growth, reproduction), and storage. Increased expenditure in one area inevitably result in less energy being available for other uses. Disease may affect the balance among uses in many ways. For example, coyotes with sarcoptic mange appear to stop feeding because of the irritation caused by their unwelcome passengers (*so they assimilate less energy*); they lose much of their hair coat (*so they have greatly increased thermoregulatory costs*); and they produce a variety of very costly inflammatory and immune defense products to combat the mites (*consuming large amounts of energy*). Severely affected coyotes seem to use up their stored energy and then die of starvation. Many of these coyotes also have bacterial infections of their skin, probably because they lack the resources to mount an effective defense against these opportunistic invaders. Some internal parasites reduce feeding by the host animal, others reduce digestive efficiency because they damage the host's intestine, and still others compete for energy directly with the animal. Other disease agents produce a high fever which is a costly form of defense. Animals with disease often grow more slowly or reproduce at a lower rate, because energy that could be used for these purposes is unavailable.

> Many of effects of disease can be related to either increased energy expenditure because of the disease, or to diversion of energy from other uses, such as for growth or reproduction.

Factors such as weather and food supply interact with disease. For example, a coyote probably has a much better chance of surviving mange in summer than in winter, simply because of the difference in energy costs for thermoregulation. There are many parasites that have negligible effects on host animals when food is readily available (because the animal is able to assimilate enough energy to compensate for the cost of the parasite). However, the same parasite may have serious impacts when food is scarce and the animal is unable to compensate for the demands of the parasite. These effects may include depressed reproduction, altered behaviour, greater susceptibility to predators or other disease agents, or even death. Understanding this interaction between living condition and disease forms the basis of one form of disease management, in which the resistance of animals to a particular disease may be bolstered by improving general living conditions, without dealing with the cause of the disease directly. Conversely, animals in poor general living conditions are much more susceptible to most diseases.

> General living conditions have a major influence on the degree of damage caused by disease.

Many techniques used in disease management depend upon understanding the population ecology of the particular disease. This is particularly true for infectious diseases, in which it is important to understand how the disease spreads among members of the population. Infectious diseases can be divided into two broad groups: microparasites which include viruses, bacteria and most protozoa; and macroparasites which include arthropods and worms. The population

ecology of these two groups is very different.
In diseases caused by microparasites, the population of animals at risk can be divided into three broad groups:

Susceptible Individuals	Infected Individuals (some of whom are infectious)	Recovered Individuals (immune or resistant)

Microparasites multiply rapidly within the host animal but infections are rather short-lived; individuals that recover become immune and can not be infected again.

Diseases caused by macroparasites are much more complex, because this type of parasite tends to produce persistent infections and animals can become re-infected continually. Both the immunity that may develop to this type of parasite and the amount of damage they cause depend upon the number of parasites present. Most individuals in an animal population have very few macroparasites, but a few animals may have many parasites and suffer severe effects.

> Infectious diseases can be divided into two broad classes, microparasites and macroparasites, the population ecology of which is very.different

For any infectious disease to continue to occur in an animal population, there must be new susceptible individuals who can contract the disease and become infected. Many methods of disease management are aimed at preventing susceptible individuals from becoming infected.. Other techniques, such as treatment with antibiotics, are aimed to speed the recovery of infected individuals. Immunization is aimed at converting susceptible individuals to a resistant or immune state without passing through the infected stage.

The rate at which a disease spreads or is transmitted among a population is a critical factor in the success of any type of management. This rate, often called the "*reproductive rate*" or R_0 of the disease, is defined as "*the average number of secondary cases that occur when an infectious individual is introduced into a susceptible population*". If $R_0 < 1$ (on average, each infected individual transmits the disease to less than one susceptible) the disease will die out. If $R_0 \geq 1$, the disease will persist and may expand. R_0 is influenced by many factors, including the density of susceptible individuals in the population. Many forms of disease management are aimed to reduce the rate of disease transmission to a point where it does not expand ($R_0 \approx 1$) or so that the disease disappears over time ($R_0 < 1$).

> Understanding the population ecology of a disease is central to any attempt to manage it.

Management and intervention in diseases of wildlife

Why attempt management? (G. Wobeser)

> Wild animals now live in an environment that has been altered by human activities. Most attempts to manage disease are made necessary because of, or to mitigate, the effects of humans.

Disease management is a costly and difficult task in any species, and particularly so in wild animals who do not attend their physician regularly, line up for vaccination, take medicine willingly, or pay their own medical bills. Because of the inherent difficulties, there must be strong and valid reasons for attempting disease intervention or manipulation of disease among free-living species. These reasons can be broken into four broad categories:

1. The disease is believed to be having a serious negative effect on the wild animal population.
2. Disease in wild animals, or disease associated with wild animals, is believed to represent a risk to human health.
3. Disease in wild animals, or disease associated with wild animals, is believed to represent a risk to domestic animals.
4. There is public pressure or a public perception that something *"needs to be done"* about a disease in wild animals.

<u>Disease has a negative impact on wild populations</u>

Many of the diseases in this category, for which management has been attempted, are:

(a) diseases that cause conspicuous mortality (piles of dead bodies) , e.g., avian cholera and avian botulism in wild waterfowl, pneumonia in bighorn sheep, electrocution of large birds of prey;

(b) cause conspicuous and disturbing clinical signs of disease, e.g., meningeal worm (*Parelaphostrongylus tenuis*) in moose, or

(c) are clearly a direct result of human actions:

- introduction of harmful substances such as lead, mercury, pesticides, and selenium into the environment
- translocation of foreign infectious diseases, such as *Elaphostrongylus* spp. and Chronic Wasting Disease of cervids and Duck Plague in waterfowl
- capture myopathy in many species

In some of these instances, such as pneumonia in bighorn sheep, the population effect of the disease is clear, particularly on local populations; however, in many other situations, the overall impact of disease on larger populations over time is unclear or unknown and, hence, the need for management is also unclear.

Disease in wild animals is a risk to human health.

Many major attempts to manage disease in wild animals have been undertaken to protect human health. In some of these situations, including rabies in many mammalian species, brucellosis in caribou, and tularemia and plague in rodents, the wild animals are also harmed by the disease. In many other situations, including Hantavirus Pulmonary Syndrome, *Baylisascaris* infection in raccoons, Lyme Disease, and many arthropod-borne virual diseases, the disease agent seems to have little or no harmful effect on the wild animal but can produce severe illness in humans.

New diseases of this type continue to "emerge" as an expanding human population has contact with animals, and as modern transportation systems allow both infected animals and humans to move rapidly among continents.

Disease in wild animals is a risk to domestic animals

The emphasis on wildlife as a potential source of disease for domestic animals has increased as infectious diseases are eliminated from their "normal" domestic animal hosts. For example, bovine tuberculosis was not considered to be a problem in wild animals while the disease was widespread in cattle; however, as the disease has been eliminated from cattle, any remaining reservoir in wild animals becomes important as a source of reinfection for livestock. Similarly, rabies in wildlife only emerged as an important topic once rabies in dogs had been controlled.

Many of the current wildlife-domestic disease problems are related to abnormal situations in which normal "*ecological barriers*" have been overcome or circumvented as a result of human activities. For example, tuberculosis in white-tailed deer in Michigan appears to be a result of abnormal crowding through artificial feeding. Farming of indigenous wild animals has provided a closer link between traditional livestock and wild animals and translocation of animals with diseases such as Chronic Wasting Disease creates a risk to wild populations outside the known geographic range of the diseases. Problems have also been identified as a result of using marine animals as part of the diet of terrestrial domestic animals.

Pressure *"to do something"* about a disease in wild animals

Pressure, public or political, may result in attempts to manage a disease without any realistic expectation that such management could be successful, that management is required or that even, if successful, it will have any significant population effect. This may result in diversion of funding from other areas of conservation that may be more valuable for the species. Management to alleviate one perceived problem may create new disease problems, e.g., artificial feeding to reduce mortality from starvation, or rehabilitation of orphans or sick individuals, may enhance transmission of infectious agents among a highly susceptible population. Release of animals that have been held for rehabilitation, where they have had access to diseases of a variety of species, might also result in introduction of novel agents into a wild population.

Management for a disease in one species under such circumstances may have serious repercussions for other portions of the ecosystem.

☞ BEFORE ☜
You
Intervene

CONSIDERATIONS WHEN CONTEMPLATING AN INTERVENTION TO MANAGE A DISEASE IN WILD ANIMALS

Key Reference: Wobeser, G. 1994. *Investigation and Management of Disease in Wild Animals*. Plenum Press, New York. pp 131-221.

INTRODUCTION

Attempts to intervene and alter the course of disease in wild animal populations are most likely to end in failure. Successes generally have been achieved only with great difficulty, persistence and expense. Thus, to contemplate such an intervention is to contemplate a major task. Most likely, the information needed to apply the full force of modern medicine, epidemiology and ecology to the disease problem at hand is not available. The political will to carry the program to completion will be very hard to guarantee. Unexpected events and unpredicted outcomes are likely to intrude. The tools and methods required to put into effect a theoretically-sound program probably do not exist. Thus, one must proceed with caution. It is essential to make a realistic appraisal of the likelihood that an intervention will be successful. The cost of the intervention relative to its potential benefits must be assessed with some precision. The factors that threaten the success of the program must be enumerated and a strategy to overcome each must be identified and made part of the plan.

Careful evaluation should precede a decision as to whether or not to intervene in a disease event. The following discussion is intended to help guide such pre-decision evaluation. The discussion is organized around a series of questions. Answering these questions for an intervention that is being contemplated will focus attention on some major issues that require evaluation prior to deciding to proceed or not to proceed with the intervention under consideration.

Question: *What is the rationale for the intervention ? Why is it being considered ?*

What problem is the intervention intended to solve ? It is essential to define completely and precisely the problem at hand: what disease, in what animals, in what place, at what time ? What is the magnitude of the problem with respect to wildlife, domestic animal or human health? What, exactly, are the goals or objectives of the intervention being considered ? For the program to be successful, what, precisely, must be achieved? Is the intervention intended to prevent a disease from occurring, to reduce the impact of (i.e. to control) a disease that already exists, or to eradicate a disease completely from the population or geographic area of concern ?

Intervention in a wildlife disease issue might be contemplated for a wide range of reasons. There is no generic rationale for management interventions, nor are there self-evident goals and objectives. These are unique to each situation and must be defined in each case, with precision and care. For the definition then becomes both the central point of reference for designing the intervention program and the yardstick by which success or failure can be measured.

Some hypothetical examples of very different disease problems that might suggest intervention are the following: 1) A disease occurs in wild and farmed trout in the northwestern United States but not in Canada. It could arrive in Canada by several routes, including imported fish or eggs and upstream fish migration, and could become established in wild trout populations. It has the potential to reduce hatchling survival by 50%, and its presence in Canada would eliminate sales of fish and fish products from important international markets. 2) One of the seven Black-footed Ferrets that make up the only wild population in the world has been found dead of Canine Distemper, a highly-contagious virus disease present in coyotes, foxes, weasels, badgers and skunks in the area. It is likely that the remaining 6 ferrets also will contract this disease and die within 3-6 months. 3) Hog cholera (classical swine fever) has been discovered in a feral pig in southern Ontario, where a small population of feral pigs and some escaped European wild boar has existed for several decades. As significant proportion of Canada's commercial pig farms are within 150km of the location where the dead pig was found. All international and interprovincial trade in Ontario pork has been halted, since this is an exotic and devastating disease of pigs that can be transmitted by infected pigs, meat or meat products.

Example number one might require an intervention to prevent the disease from arriving in Canada. Goals and objectives would be centred on exclusion of the disease from entry into Canada by all known potential routes. The rationale for action is the potential harm the disease might cause and the high probability that it will arrive in Canada if measures are not taken to exclude it. Example number two identifies a problem with a disease that is wide-spread in a large range of different host animal species but poses a high risk of extinction to one susceptible species. The rationale for intervention is to prevent extinction of the Black-footed Ferret. Goals and objectives must be centred on lessening the impact of the disease on the six remaining ferrets, since the disease has too many different hosts and too wide a distribution to make eradication possible. Example number three is an occurrence of an exotic, foreign disease in free-ranging animals. The rationale for intervention is the enormous economic consequences of the disease for Canadian agriculture. Preventive measures already have failed. Eradication is likely to be the objective of intervention in this situation, since only eradication will return Canada to its previous status of being free of this disease.

Often, it is easier to justify, and to acquire support for, an intervention to manage a wild animal disease when the disease poses some risk to the health of domestic animals or people, or if it is seen to have an important impact on human economies or other values, as is the case with some disease issues affecting game animals or endangered species. All of the examples given above would likely be viewed by managers and by society as justified interventions. This is not always the case. Proposals to eradicate economically-important diseases from bison in national parks by eliminating the infected populations have met with strong resistance, as have proposals to prevent the possible introduction of diseases into wild animal populations by disallowing the use of llamas as pack animals in remote areas. Thus, clear articulation of the rationale for an intervention, while essential, does not guarantee that the program will receive public or political support.

To establish goals and objectives for an intervention, wildlife personnel must have a substantial knowledge of the biology of the disease and the populations of host animals in question. What is the prevalence and distribution of the disease or disease-causing agent ? Is it present or absent from the areas and populations of concern ? What are its host range, its modes and rates of transmission, its vectors and reservoirs ? What is the number, density, reproduction rates and related demographic information of the host population? Only with such knowledge in hand is it possible to assess the feasibility and predict the effects of various methods of intervention. It is not sufficient to have as an objective a vague intention such as "to vaccinate the population against the disease". Objectives must be much more precise; for example "to vaccinate at least 65% of the population (all ages) and thereafter 70% of young of the year each year for 15 years". Such precise objectives can only be derived from knowledge of the rate of transmission of the disease and the density, distribution and reproductive rate of the host population.

Question:	*What methods can be used to achieve the goals and objectives ?*

The full range of possible methods should be evaluated before any particular method is chosen. Methods that at first seem the most familiar and feasible may turn out to be costly and unlikely to succeed. For example, killing some or all of a host animal population is often the method first selected by wildlife managers when suddenly required to control or eradicate an infectious disease. Yet, experience shows this approach seldom is successful. The full range of approaches to interventions in disease occurrences includes methods directed at the disease-causing agent, at the host population, at habitat and environmental factors and at human activities. All must be considered.

Question:	*<u>Exactly</u> what do you plan to do ?*

Once a method has been selected, it is essential to make a <u>detailed plan</u> of exactly how that method will be applied: in what area, to what species and populations, over what period of time? Who will do it, and with what equipment and materials ? What special training will be required and who will provide that training ? A detailed plan is needed <u>before</u> a final decision is made whether or not to intervene. Such a detailed plan often will identify practical difficulties and costs that have been overlooked in the initial, more general planning. The magnitude of the program will be more clearly evident, which in turn will contribute importantly to the decision on intervention.

Question:	*What hazards are associated with the proposed intervention ?*

Some proposed interventions in wildlife disease events will include methods that pose some risk to people, animals, environments or economies. Poisoning campaigns kill non-target species and sometimes people. Manipulations of the environment may have secondary effects unrelated to disease management. Vaccines and medications may be hazardous to non-target species. Removal of a disease or a host species may alter the local ecology in ways harmful to various human values, whether economic or aesthetic. Thus, the safety and non-target impacts of the proposed intervention program require assessment. In some cases, they will be found to be trivial; in others they will be found to be prohibitive.

Question:	*How much will the intervention program cost ?*

A realistic appraisal of the cost of the program must be made in advance. Programs intended to prevent or to control disease usually are on-going programs; once initiated, they must be carried out continuously into the foreseeable future and beyond, and thus they must have continuous financial support. Eradication programs have defined end-points, but often require years or decades to complete. Failure to complete such programs will mean failure to eradicate the diseases; all the money and effort expended on the program will have been wasted. Cost can only be estimated when the objectives, goals and detailed methods of a proposed program have been determined. However, the cost estimate is equally important to determining the overall feasibility of a proposed intervention. It is particularly important to have made a realistic appraisal of the duration of the program and the likelihood that sufficient funds will be available to carry the program to completion. The final stages of an intervention often are as costly as the initial stages, but the apparent results of the program, in its final stages, can be minimal. For example, it might take 15 years to eliminate a population of wild ungulates from a defined area of boreal forest in a disease eradication program. The hunting effort in the last five years would have to be the same as during the first five years, but the number of animals killed during the last five years would be very small if the program is being successful. Will there be funds available to sustain this effort when very few animals are being found and killed ? If not, many millions of dollars, animal lives and years of effort will have been thrown away on the first half of the program while eradication of the disease will not have been achieved.

Question:	*How will success be measured ?*

Every disease intervention plan must include methods and budget to measure the success of the program. The objectives and goals of the program define what must be measured. To assess the success of a program to prevent disease from becoming established, there must be some measure of the continued presence of the disease in the source areas of concern and of its absence in the area and populations being protected by the program. The success of a vaccination program can only be assessed by determining what proportion of the target population has actually been vaccinated and the level of immunity to disease that has been achieved. A program to reduce mortality from a particular disease can only be evaluated by measuring the actual mortality due to that disease before and after initiation of the intervention program. In this aspect, intervention in a wildlife disease event is no different than other wildlife management interventions; there must be some way to assess the effectiveness of any management action. The whole approach of "adaptive management" is based on accurate evaluation of the effects of management interventions. Thus, evaluation of the effectiveness of the disease intervention must be an integral part of the program, fully developed in the planning stage. If the effectiveness of the program can not be measured, it is likely that there also is no defendable rationale for the program in the first place, since accurate assessment of the initial problem and of the effectiveness of the intervention to solve that problem usually will require the same methods.

Question:	*What are the principle threats or obstacles to success of the program, and how will these be overcome ?*

Not every proposed intervention in a disease event will attract attention or controversy, but some will; in the latter case, the success or failure of the proposed program may hinge as importantly on issues of public opinion as on rationale, science, methodology or finance. Legislation may exist that prevents certain actions from being taken or requires a lengthy approval process. All such threats and obstacles to the implementation of a proposed intervention should be identified in advance. Furthermore, approaches to overcoming these obstacles must be part of the plan. Often, these obstacles will require that considerable effort be expended on public education programs that fully explain the rationale of the proposed action and seek understanding and agreement in advance of implementation of the program itself. These aspects of a successful program can not be ignored.

Management and intervention in diseases of wildlife

Basic strategy choices (where is the weak spot?) (G. Wobeser)

After considering the reasons for intervention, and clearly defining the objectives or goals of the management, the next step is to develop a plan of action. There are four basic levels or types of management: do nothing, prevention, control, and eradication.

Do Nothing about Disease

After considering the desirability and feasibility of various actions, the most appropriate conscious management decision may be that action is not required or possible.

Doing nothing may be likened to deciding that water in the area is not the problem and effort would be better spent enhancing upland habitat.

Prevention of Disease

Prevention of disease involves excluding the occurrence of a disease in either individual animals or in populations, where it does not already occur. A common form of this type of management is preventing the entry or release of a harmful substance or agent into an area where it is not present. Examples include legislation to prevent translocation of animals from an area where a parasite is known to occur to an area where it is not present. Similarly, bans on the use of certain chemicals in the environment are designed to prevent poisoning. Immunization can be used to prevent the occurrence of disease in individual animals. The basic assumption is that the disease is not present, and effort is directed toward preventing it from occurring.

Prevention can be likened to standing on dry land while building a dike in anticipation of rising water.

Control of Disease

Control, in the narrow sense, is used when a disease is already present, either in the individual or in a population, and effort is directed toward either reducing the frequency of occurrence of the disease or reducing the harmful effects of the disease. The assumption is that the disease will continue to occur in the area but at a reduced level. This type of management requires establishing some type of goal related to the level of disease that is acceptable or tolerable. At the individual animal level, treatment might be used to reduce the damaging effects of the disease. At the population level, restrictions might be placed on how a pesticide is used to reduce the likelihood of wildlife poisoning. There must be the recognition that control will need to be continued in perpetuity to maintain the desired effect.

> *Control can be likened to bailing water while floating, in the hope that the water can be lowered sufficiently, so that bailing can then be continued while standing in water up to your knees.*

Eradication of Disease

Eradication involves the total elimination of an existing disease. This requires a herculean effort. However, a few wildlife diseases have been eliminated in an area or region. Eradication is usually much more feasible for non-infectious than for infectious diseases (because infectious agents have the nasty habit of reproducing) and it is likely only possible for a selected group of disease agents that produce readily identifiable disease, have a narrow host range, and do not occur in a clinically silent form. Only one infectious disease (human smallpox) has ever been completely eradicated. The major problem with eradication programs is that once a disease has been almost vanquished, and is very rare, concern, funding and effort wane, allowing the disease to recover.

> *Eradication can be likened to standing or floating while bailing, in the expectation that all the water will be removed and you can then stand on dry land to build a dike to prevent its reentry.*

Within these three broad classes of management, effort can be directed at:

- attacking the causative agent or factor
- manipulating the animal population
- manipulating other aspects of the environment
- altering human activities
- some combination of all of these

In most situations, the last option, a combination of approaches is required, and disease management projects that have relied on a single method have often failed . Different approaches may be required at different stages on a program. For example, the first objective may be to lower the overall prevalence of the disease over a large area, then to concentrate effort in those areas where the disease is at a disadvantage, and finally to use extremely intense methods on the final pockets of the disease.

Management and intervention in diseases of wildlife

Attacking the causative agent or factor* (G. Wobeser)

The most direct method of managing a disease is to eliminate its cause. This requires that (a) the cause is known, and (b) some method exists for preventing the cause from reaching the animal(s) or causing disease. Each of three basic strategies: prevention, control or eradication may be employed.

Prevention of entry of a causative factor into an area or population is usually the simplest and most effective method. Wildlife management is replete with examples of disease problems that have been created by the unintended, negligent, or occasionally intended introduction of agents that have done harm to wildlife, e.g, *Elaphostrongylus rangiferi* into Newfoundland and then into Maine; *Fascioloides magna* to European deer; mercurial seed dressings for fungus control. Techniques are now widely available to reduce or prevent such occurrences in future. Prevention has the obvious advantage that the disease is dealt with before damage results to the individual animal or the population.

It is usually easier to manage a non-infectious cause of disease, such as a man-made poison, than it is to attack an infectious agent. Poisons (with the exception of some biological toxins) do not multiply or replicate, so that the poison present in the environment will disappear over time, provided that no more is added. Management of mercury and certain pesticide poisoning of wild birds provide good examples of effective programs. Management of lead poisoning of waterfowl has been less successful in the short term. No method currently exists for attacking the causative agent of avian botulism.

Attempts to manage the causative agent of infectious diseases is complicated by reproduction of the agent and spread to new members of the population. The nature of the causative agent is very important, and two broad categories have been described:

<u>Endogenous agents</u> can be present in healthy animals without causing disease or are ubiquitous in the environment, but can opportunistically infect and injure animals that are weakened in some other way. (Perhaps because of shortage of energy to mount an effective defense). These agents are very difficult to manage because of their ubiquitous and covert nature. Examples include *E. coli* bacteria and *Aspergillus fumigatus* fungus.

<u>Exogenous agents</u> are not present in healthy animals and are usually acquired from outside sources or other infected individuals. They produce well-defined disease (that is readily recognized) after infection. Examples include rabies and canine distemper viruses, and the bacteria that cause plague and tularemia. Because potential sources of infection are more limited, these disease are more amenable to management.

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* The term causative agent is usually used for infectious diseases, while the term causative factor is usually applied in non-infectious diseases

Infectious agents might be attacked before the animal has been infected, or after the agent has entered the animal's body. The former has the obvious advantage that the disease is dealt with before damage results to the animal. Possible methods that have been used for disease management by attacking agents outside the body include disinfection and sanitation. Disinfection has not been widely used and its effectiveness under field conditions is unknown, e.g., attempted chlorination of wetlands for duck plague virus. One of the standard techniques used in many diseases is to collect and dispose of the carcasses of animals dead of a disease as a method of reducing the amount of contamination of the environment. This technique would appear to most suitable for diseases in which the causative agent will persist for some time in the external environment. In North America, sanitation has been used in anthrax outbreaks in bison, and avian cholera and botulism in waterfowl. The effectiveness of this technique in reducing mortality has never been tested.

Another potential point of attack is through reducing the availability of vectors that enhance transmission of infectious agents. Vectors are usually invertebrates that may or may not be required for the transmission of various diseases. While it is very attractive to consider control of vectors such as mosquitos that transmit many viruses, or snails that transmit parasites, such programs have had limited success because of acquired resistance to the control method, the need for massive treatment, and the effects on other parts of the environment. An example in wildlife is the use of pesticides to control fleas that transmit plague among wild rodents.

In human and veterinary medicine, many infectious diseases are managed by attacking the causative agent within the infected individual, through the use of drugs such as antibiotics and anthelmintics. A disadvantage of this approach is that the host has already born some of the costs of the infection prior to treatment. There is no reason to expect that drugs of this type would be less successful in treating wild animals than they are in treating the same diseases in domestic animals; however, the problem lies in identifying appropriate wild animals for treatment and then delivering the treatment to the animal. Limited trials involving treatment of parasites including lungworms and psoroptic mange in bighorn sheep, and intestinal parasites in red grouse have had mixed results. Treatment may be most useful in reducing the probability of translocation of diseases when animals are moved, but it cannot be relied upon to eliminate the risk of such transfers occurring. Widespread programs to treat large segments of the human population with drugs to control infections have generally failed, because of rapid development of resistance by the disease organism.

MANAGING THE HOST POPULATION

Key Reference: Wobeser, G. 1994. *Investigation and Management of Disease in Wild Animals*. Plenum Press, New York. pp 131-221.

INTRODUCTION

Changes in the host animal population can radically alter the occurrence and dynamics of disease. Changes in the number, density or distribution of host populations affect transmission among hosts of contagious infections agents and also affect the probability that susceptible hosts will contact infectious or non-infectious causes of disease. It also is possible, through vaccination, to alter the proportions of susceptible and non-susceptible host animals in a population which, in turn, may reduce the prevalence of disease substantially, even to the point of eradication.

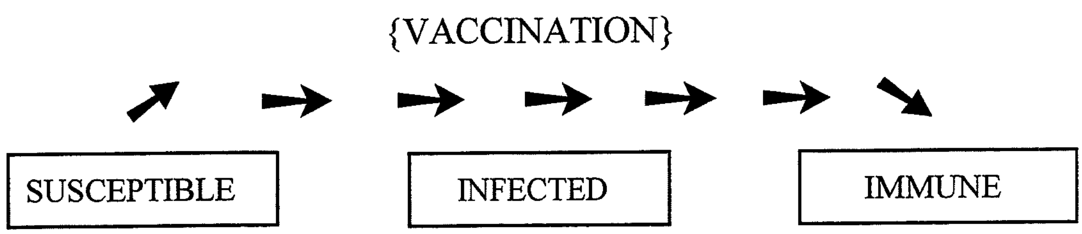
IMMUNITY OF HOST POPULATIONS - INTERVENTION BY VACCINATION

It is possible to protect an animal from some kinds of infection, or from disease despite infection, by vaccination. In general, vaccination is effective against infectious organisms that normally produce strong and lasting immunity in animals that survive natural infections. Such is not the case for many infectious organisms, but it is true for some. Vaccination also can be effective in protecting animals against some toxins, such as the bacterial toxins that cause botulism.

Vaccination, when it is effective, can influence disease in animal populations in three different ways: It can result in eradication, or control of the prevalence of infection that reduces the negative impact of the disease on the population, but it also can worsen the negative impact of a disease on a population. This latter effect is not at all intuitively evident or expected but is, nonetheless, well-documented in some situations. This emphasizes that vaccination may be harmful as well as beneficial, depending on circumstances. Vaccination also may be completely ineffective at altering the occurrence of disease in a population. Thus, as a management tool for disease in animal populations, vaccination must be considered only after close examination, including use of mathematical models. As a tool to protect individual animals from disease, vaccination can be very effective and easily applied. Even here, however, caution is needed; some vaccines that protect one species from a disease will cause the disease in another species; many valuable animals have been killed with vaccines originally developed for other species.

About Vaccination: The effect of vaccination on the occurrence of disease in an animal population can be approximated in the following simplified scheme. A population can be conceived to consists of animals of three different categories with respect to an infectious disease against which a vaccine might be used: susceptible animals, infected animals that are capable of spreading infection to susceptible animals, and animals that have recovered from infection and are now immune and no longer susceptible to the disease.

In this scheme, disease transmission occurs only from infected to susceptible animals; immune animals no longer participate in disease transmission. Vaccination moves susceptible animals directly into the immune group without passing through a period of infection during which each might transmit infection to susceptible individuals.



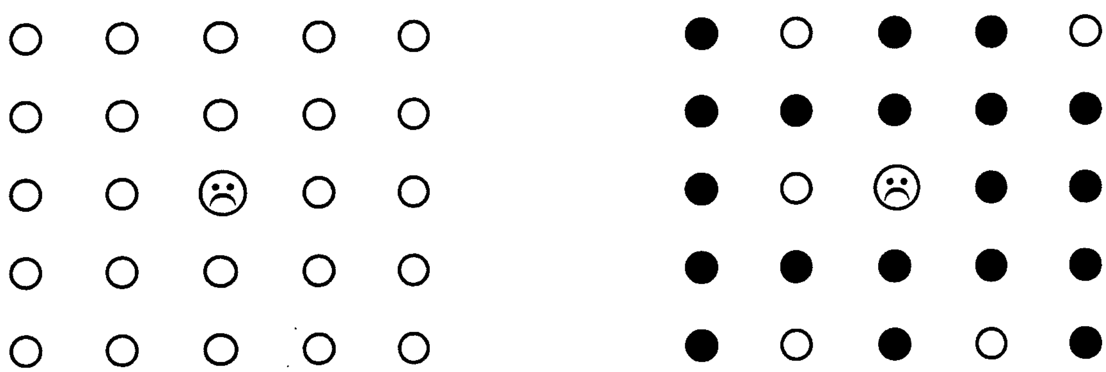
Without delving into the mathematics of disease transmission, it is reasonably evident that disease transmission among individual animals in a population will be slower, less efficient, less likely, as the proportion of immune animals in that population increases and the proportions of susceptible animals and of infected animals decrease.

Vaccination and Disease in Wild Populations How does vaccination affect the infectious disease itself? Infectious disease is a parasitism whereby the infectious agent grows and reproduced itself in the host animal. To continue to exist, infectious agents must manage to be transmitted from infected individuals to new, susceptible individuals. Diseases against which vaccination is effective usually produce infection for a rather short period of time, and then either the host animal dies or the immune system of the host animal kills off the infectious agent; if the agent does not manage to be transmitted to a susceptible host in this short period of time, it will die. Epidemiologists who study disease transmission have come up with a measure of the ability of infectious organisms to be transmitted from infected hosts to susceptible hosts. This measure is called the "basic reproduction ratio", symbolized as "R_0". The basic reproduction ratio for an infectious agent is the number of susceptible individuals that would become infected if a single infected individual were introduced into a population of susceptible individuals. This basic reproduction ratio is not a fixed property of an infectious disease but also depends on the population density, age structure, proportions of susceptible and immune individuals and other details of the host-parasite relationship that can vary with circumstances.

R_0 can be looked at as a ratio of the "birth rate" to the "death rate" of an infectious disease. Just as in an animal population, for a disease to persist in a population of host animals, this ratio must be equal to or greater than one ($R_0 \geq 1$). If it is less than one ($R_0 < 1$), the disease will die-out: eradication will occur. Without doing any algebra, this general concept is logical and makes sense. In the two schematic figures below, it seems self-evident that a disease that arrives in a population of animals in one infected host animal is likely to spread and infect many more animals in Scheme A than in Scheme B:

● = Immune Animal; ○ = Susceptible Animal; ☹ = Infected Animal

Scheme A — Scheme B



Thus, for the same disease, R_0 is larger is Scheme A than in Scheme B. The purpose of using vaccination is to create Scheme B: to reduce R_0 to less than one and achieve eradication, or to reduce R_0 to some acceptably small number in order to decrease the amount (prevalence) of disease and its affect on a population.

What proportion of the population must be vaccinated to achieve the desired level of control or to achieve eradication ? This is the crucial question that must be answered when evaluating the possible use of vaccination in a management intervention. To estimate the proportion of the population that must be made immune to the disease by vaccination, accurate information about the population biology of the host population and the behaviour of the disease in that population must be available. In general terms, there is a critical proportion of the host population that must be immune to a disease in order to make R_0 less than one ($R_0 < 1$). This is different in every particular situation, just as R_0 is different in every particular situation, even for the same disease. However, this critical proportion must be estimated. To make this estimate, R_0 must first be measured or known. Then, the minimum critical proportion of the population that must be made immune in order to achieve eradication of a disease is: $1 - 1/R_0$. Below is an example of how the proportion of the population that must be made immune to a disease if the disease is to be eradicated is different, depending on the basic reproductive ratio (R_0) of the disease in the population of concern:

Basic Reproduction Ratio of the Disease (R_0):	2	4	6	8	10
Proportion of population that must be vaccinated to eradicate the disease (R_0 <1):	50%	75%	83%	88%	90%

Smallpox was eradicated from the world's human population through vaccination; R_0 for Smallpox was estimated to be 3.73 in Africa and 5.71 in India, requiring vaccination of 73% and 83% of the human population, respectively. R_0 for measles in dense human populations is about 18 !

It would be an awesome task to achieve immunity through vaccination even in only 50% of a population of wild animals; 90% is, more or less, unimaginable. Every birth creates a new, susceptible individual. Unless or until eradication is achieved, vaccination must be a continuous, intensive and very expensive method of intervention.

Rabies in wild carnivores has been both controlled and eradicated through vaccination, a remarkable achievement (vaccination against rabies is explored in detail later in this course). Vaccination has been attempted against other diseases. Small populations of rare African ungulates have been successfully vaccinated, individual by individual. Some decrease in the incidence of abortion in elk caused by Brucellosis has been achieved by vaccination in the United States. Vaccination of bison in Canada against anthrax proved highly problematic and not effective.

About Vaccines: Vaccines act as surrogates for an infectious organism or other cause of disease. The vaccine contains whole organisms or parts of organisms that cause the host to mount an immune response just as it would against infection. There are at least four different kinds of vaccines: 1) live vaccines in which the host animal is exposed to a form of the living infectious agent that has been altered in some way so that it does not produce disease but does cause an immune response. These vaccines produce infection without disease; 2) killed vaccines in which the infectious agent is dead but is administered in a form that stimulates an immune response ; 3) fragment or component vaccines in which some particular molecules from the infectious agent are used and the immune response against these pieces of the infectious organism is sufficient to protect the animal from infection; 4) live recombinant vaccines which consist of genetically-engineered viruses that contain some piece of the genetic make-up of the infectious agent of concern. Vaccination consists of infection with the engineered virus, which does not cause disease but lives in the host animal long enough to stimulate an immune response. That immune response includes a response against some molecules encoded by the genes of the infectious organism of concern that are carried and expressed on the recombinant virus. The immune response against these molecules provides protection against infection. Vaccines that protect against botulism and some other bacterial toxins consist of the toxin made non-toxic by chemical treatment but which retains the ability to stimulate an immune response against the toxin. These are similar to "component vaccines".

Live vaccines (#'s 1 and 4 above) generally are the most effective and also potentially the most hazardous. Live vaccines are designed for use in a very small number of host animal species. In other species, these live viruses may actually cause disease. Thus, some live vaccines for rabies in dogs and cats and for canine distemper in dogs have caused rabies or distemper when used on species for which they were neither designed nor tested (wild rodents; ferrets and panda's, respectively). The live recombinant vaccines consist of a live carrier virus with some added genetic information from the infectious agent of concern. The carrier virus itself has the potential to cause disease and must be tested in a wide range of animal species before it can be considered safe. These live, genetically-engineered vaccine viruses also have the potential to become infectious agents in their own right, agents that persist in animal populations, transmitted from animal to animal like any other infectious agent. Most carrier viruses are selected and tested to ensure that they are not contagious, but contagiousness may be an unintended result if such vaccines are not adequately tested. Contagiousness and self-propagation in the wild is the express intent of at least one recently-developed vaccine against Viral Hemorrhagic Disease in European rabbits. In contrast, vaccines that consist of killed infectious organisms or their components carry none of these risks, but also often require multiple exposures to achieve the same level of immunity as can be achieved by a single exposure to a live vaccine.

Delivery of Vaccines: How do you vaccinate wild animals ? A variety of methods have been used. In some settings, such as urban skunks and raccons, animals are trapped, vaccinated and released. This approach also was used to vaccine bison against anthrax - round-up and vaccination by conventional needle and syringe. Vaccines have been delivered with rifle-shot darts from aircraft and encased in bio-degradable bullets (BioBullets ®) shot into congregated ungulates from the back of a truck. These methods are only feasible when applied to small groups of animals is local areas or to a small number of individual animals of high value that can be located and approached. For delivery of vaccine over a large geographic area, the only method applied successfully has been delivery of oral vaccines in attractive baits. This approach has been successfully used against rabies in foxes and raccoons in Europe and in North America. These programs began with development of vaccines that were effective when given by mouth and safe to non-target species, and development of baits and bait delivery methods specifically and differently for foxes and for raccoons.

Vaccination can be ineffective or harmful: It is incorrect to think that vaccination, if it does no good, at least will do no harm. The previous section emphasized the risks posed by live vaccines and genetically-engineered vaccines. In addition, vaccination has been shown to make disease worse, rather than better, in at least one disease in people, and this should be taken as a serious warning signal for use of vaccination in wild animals. In North America, mass vaccination against Rubella (German Measles) was quite effective in reducing the incidence of childhood disease. Childhood rubella is, in general, a fairly mild disease. However, an unexpected effect of this vaccination program was to increase the number of women of child-bearing age that were not immune to the disease because they had not themselves been vaccinated yet were protected from infection by the increased number of immune individuals vaccinated in childhood. Rubella is a very serious disease in pregnant women, with severe effects on the fetus. The incidence of severe Rubella in pregnant women actually was increased as a result of a successful vaccination program aimed at the childhood disease. The harm done by Rubella, overall, probably was increased. Such are the vagaries of the complex relationships among hosts, diseases and immunity in dynamic populations.

Vaccination: Yes or No ? In considering use of vaccination in a management intervention, both the risks and the effectiveness of the available vaccines must be fully evaluated. It is most likely that no effective and safe vaccine exists for the disease of concern in the host species of concern, and also that no effective method exists to deliver the vaccine to a sufficient proportion of the population to alter " R_0" significantly. Thus, a period of research, vaccine and method development and testing may be required before vaccination can be applied as a management tool.

Vaccination has the potential to eradicate disease or markedly alter the effect of a disease on an animal population. However, its use carries many hazards and a high probability of failure. Vaccination can readily be used to protect small numbers of individual animals from a particular disease. To alter the course of disease in an extensive wild population, vaccination should be considered only after applying the best available mathematical models to the problem at hand. Such models provide the only means to estimate the magnitude and nature of the vaccination program that will be required. A central reference to be consulted is Anderson, R.M and May, R.M. 1991. *Infectious Diseases of Humans: Dynamics and Control.* Oxford University Press, Oxford.

MANIPULATING NUMBER, DENSITY OR DISTRIBUTION OF HOST ANIMALS

Just as vaccination can alter the host animal population by changing the relative proportions of susceptible and immune animals, other kinds of changes in the population of host animals also can alter the course of disease in that population. These may be applied over a wide range of scales: from local manipulations such is dispersal of animals away from a source of poison to broad programs to alter distribution or population density over large areas. The objective of such manipulations usually is to reduce contact between disease-causing agents and host animals or to reduce transmission of disease among individuals of the host species.

Change in Animal Distribution:

1. **Dispersal**: When disease occurs suddenly at a specific location, dispersal of susceptible animals away from the area seems a logical intervention in order to reduce transmission or further occurrence of the disease. Dispersal carries little risk when the disease of concern is not contagious but rather occurs because animals contact the disease-causing agent in a particular environment. Botulism, poisoning from environmental contaminants and most instances of Anthrax are diseases of this type. In outbreaks of contagious infectious diseases,

dispersal carries with it the risk that the disease, as well as the host animals, will be dispersed away from the site of the local outbreak, since infected animals are likely to be driven out of the area. This has been a major concern, for example, in the management of hog cholera (classical swine feer) in wild boar in France in the one small area on the German border where it occurs. Whether or not dispersal of the disease represents an important risk will depend on the particular situation. Other complications can include increased depredation on agricultural crops by the dispersed animals.

Dispersal is not easy. Few techniques are effective. Thus, while sometimes a good idea in theory, in practice, dispersal often is not achieved. In general, to deter animals from occupying an area for any period of time requires a great deal of effort. Hazing with aircraft must be continuous. Scare cannons and similar deterrent devices seldom have lasting effects; animals become habituated to them. Large animals like bison do not take directions readily. Sometimes it is possible to lure animals away from small areas with food or to manipulate hunting activity to drive animals onto protected habitat.. Whatever the method used, there must be alternative habitat for the animals being displaced if dispersal is to be effective.

2. **Fences**: Fences have been used to keep wild animals and domestic animals separate to prevent transmission of diseases between the two groups. Elk Island National Park, for example, is entirely enclosed and has dealt with important infectious disease within its fenced borders that did not escape to the outside. Some large parks in South Africa are fenced. A fence 268 km long and 2 M high was built in the 1940's in east Africa to keep wild ungulates infected with rinderpest from spreading the disease along their normal migration route. However, fences are very expensive, require constant maintenance and, quite often are ineffective because they can not be properly deployed. The 268 km of fence in Africa lasted less than 2 years. Construction of fences often requires a broad swath of habitat destruction. All in all, fences seldom are practical methods for intervening in a disease event except as a means of keeping animals out of very small areas such as sites of environmental contamination, thereby reducing contact between the animal and the causative agent of disease.

Removal of Diseased Animals - "Test and Slaughter"

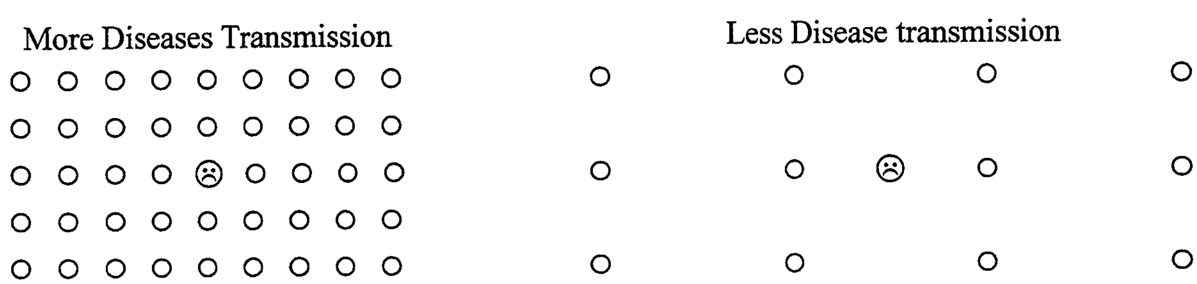
If the infected individuals in a population could be identified and removed, eradication of a disease would seem possible by this means, or an on-going program of this sort might markedly reduce the prevalence of a disease in a population, thereby reducing its impact. In practice, this approach can apply only when two conditions are met: 1) Infected individuals are easily identified and 2) the disease spreads slowly within the host population. Recognition of infected animals requires that there be a reliable test that distinguishes infected from non-infected animals. This is not the case for every disease and most tests require that animals be captured at least long enough to secure a blood sample. Thus, in practice, this approach is limited to the few diseases that meet the two essential criteria given above and that occur in populations of animals from which individuals can readily be captured for testing. Test and slaughter was used successfully to eradicate Brucellosis from bison the totally confined population of bison in Elk Island National Park. However, there have been few such successful applications of this approach to disease control in wild populations.

Removal of Non-Infected Individuals - "Test and Foster"

In a few instances, attempts have been made to establish disease-free groups of animals by removing from an infected wild population individual animals that are not infected. Such programs of capture and testing are always coupled with programs of captive propagation of the animals with the intention of future release back into the wild. In the mean time, it is hoped that the infected wild population will be eliminated or that disease-free habitat elsewhere is or will be available for the animals thus saved. The Hook Lake Bison Project (NWT) is embarked on such a program, whereby bison from a herd infected with Tuberculosis and Brucellosis are captured as young calves, raised in captivity, allowed to reproduce in captivity and their progeny are destined for re-introduction programs. Tests for the two diseases are conducted repeatedly throughout the program. A similar program has been used to save the Arabian Oryx from Tuberculosis, and the last Black-footed Ferrets from Canine Distemper.

Reducing the Density of the Host Population

As noted in the discussion of vaccination, the basic reproduction ratio of an infectious disease, R_0, is affected by the density of the host population: the denser the population, the more likely is R_0 to be high, and thus the more readily will the disease spread among individuals in the population. This is not a uniform relationship that is the same for all diseases in all host species; R_0 is affected by multiple factors in the host-parasite relationship and in the population biology of both the host and the infectious agent. However, where disease transmission involves contact between infected and non-infected individuals, it seems generally logical that transmission will occur less readily when population densities are low:



There are several ways the density of the host population might be reduced:

- Increase mortality (kill animals)
- Increase the area of habitat occupied by the population
- Emigration (translocation of animals)
- Decrease reproduction (selective killing, sterilization)

None of these is readily accomplished, but each may be appropriate in a particular situation. Unfortunately, in most real-world situations, neither the basic reproductive ratio (R_0) of the disease in the population of concern nor the density of that host population will be known. Thus, it is difficult, at best, to estimate what degree of reduction of population density is required (and of what ages and sexes) to achieve the level of R_0 needed to control or to eradicate the disease.

Population reduction by killing animals has been applied in at least three different ways: 1) to particular small locations where a host species is eliminated completely to halt an outbreak of disease; 2) to create host animal-free zones to act as barriers to the spread of disease; and 3) eradication of the host animal population over a large geographic area. For example, Alberta responds to the occurrence of rabies in skunks by local depopulation of skunks at the outbreak site (30 km radius). Barriers have been used to keep rabies in red foxes out of Denmark, and a barrier program currently is in place in an attempt to prevent disease-free bison to the north and west of Wood Buffalo National Parks from contacting diseased bison within the Park. A massive, province-wide campaign of predator depopulation was undertaken in Alberta in the 1950's to stop an incursion of rabies from the north (over 180,000 animals killed) .

There are major difficulties associated with achieving and maintaining reduced population densities by killing animals. The depopulation effort is constantly countered by reproduction and immigration. Animal populations often recover very quickly after depopulation; for example, red foxes in Europe reduced to 20-30% of their former population density recovered to previous levels in about 4 years, and in eastern North America it was estimated that reduction of red fox populations by as much as 60% would have no detectable effect in a year's time. Attempts to achieve eradication of wild water buffalo and wild pigs in Australia have failed and, in hindsight, were considered simply impossible to achieve, regardless of effort. On the other hand, sophisticated approaches to achieving virtual eradication of vampire bats in front of advancing epidemics of rabies have been highly successful. These latter programs were based on extensive research into bat biology and the epidemiology of rabies in vampire bats, and employed aspects of bat behaviour in the design of the program.

Removal of animals by moving them to un-occupied habitat elsewhere appears to have been successful in at least one situation. All-age die-offs of Bighorn Sheep from severe pneumonia occur from time to time, associated with a complex of causal factors, of which high population density on limited habitat seems to be of major importance. Translocation of substantial proportions of sheep populations that had reached a high density appears to have been successful in averting such die-offs. Such programs are costly and require that there be habitat available for the translocated animals.

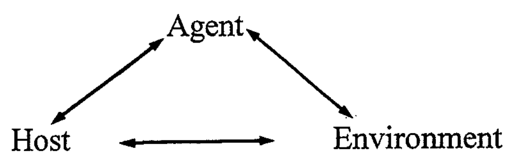
At least two quite different strategies have been used or contemplated to reduce the rate of reproduction in a host animal population as a means of controlling population density. One approach is selective killing that includes substantial numbers of reproductive-age females and young-of-the-year. This strategy, achieved through hunting regulations, appears effective in controlling moose populations in Sweden, for example. The other approach is to achieve sterilization of a proportion of the adult population sufficient to reduce reproduction rate.

Vaccines, chemical agents, and surgery all have been proposed, and some have been tried. This approach has all the problems inherent in other programs of vaccination or that require handling and treatment of individual animals. Some populations of feral cats have been controlled in this manner.

Management and intervention in diseases of wildlife

Manipulating the environment for disease management (G. Wobeser)

Managing disease by manipulating features, other than the host population or the causative agent is based on the concept that disease represents an interaction among these three factors and that by changing the environment, the other two factors can be influenced in a manner that reduces the occurrence or impact of disease.



This approach probably represents the most promising method for managing many disease in wild animals; however, a much greater knowledge of the ecology of the disease is required for this technique to be effective than is required to inject antibiotics into an animal to control an infection, or to disperse animals away from a site of toxin. Environmental factors may operate on vastly different scales and important features may vary from continental weather patterns to the relative humidity in the microclimate under leaf litter on a forest floor.

Environmental manipulations may be used in many ways. The simplest is to modify the environment to remove a risk factor. Examples of this approach include:

- modification of electrical transmission lines to reduce the probability of electrocution of large birds,
- routing overhead wires away from bird migration paths to reduce direct mortality as a result of collisions, and secondary occurrence of botulism that occurs when bird carcasses fall into wetlands and form substrate for toxin production,
- cultivation of wetlands to make lead pellets less available to waterfowl
- burning to reduce tick numbers
- construction of freshwater drinking sites to reduce salt poisoning of ducklings on saline marshes

The environment also can be modified to reduce disease transmission. Examples include:
- draining and clearing to reduce waterborne transmission of avian cholera among nesting eiders.
- draining to remove habitat for vector species, such as mosquitos and snails
- providing alternate habitat to reduce population density and water contamination by waterfowl.

Habitat can be modified to alter host animal populations, to reduce the occurrence of disease through:

- improvement of habitat conditions to improve the general condition of animals and, hence, their ability to resist disease.
- provision of alternate habitat to encourage animals to use areas remote from risk factors.
- alteration of habitat to reduce the population density of a species involved in disease, e.g., removal of denning sites for skunks and raccoons in areas where rabies is considered a problem.

Disease management through environmental modification is likely to be a more gradual process than direct actions involving the agent or the host species, but the results are more likely to be long-lasting.

An important factor in disease management is prediction of the effects of proposed (new) environmental modifications on disease in wild animals. This sort of prediction might include situations such as:

- anticipating the effects of global warming on the occurrence of botulism on the prairies
- predicting that widespread irrigation will increase the probability of mosquito-borne diseases and parasites that are transmitted by snails
- predicting that using domestic sheep for forest management is likely to result in increased disease problems in mountain sheep if the species have contact, and is likely to result in disease in the domestic sheep if they overlap with wild ungulates that carry and *Fascioloides magna.*

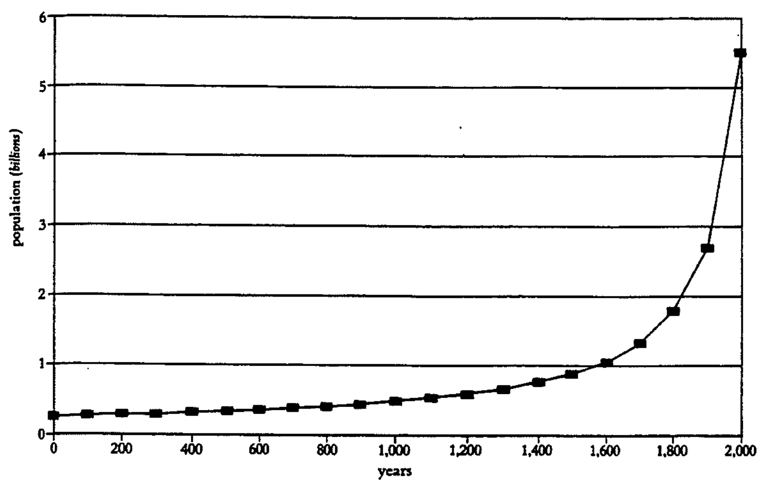
MANAGING PEOPLE TO

MANAGE DISEASE

Key Reference: Wobeser, G. 1994. *Investigation and Management of Disease in Wild Animals*. Plenum Press, New York. pp 131-221.

INTRODUCTION

The human population of the earth is immense and still growing, as depicted below:



Whatever the medium-term outcome for our ecology, survival or quality of life will turn out to be, at present, human activities occur on such a tremendous scale that they have an impact on everything, including the management of disease in wildlife. Thus, as is also the case with all other aspects of wildlife management, much of what can be done to intervene in a wildlife disease event involves changing, limiting or directing human behaviour and activity.

The ways that human activities can affect disease in wild animals are too numerous, various and interconnected to be listed and then considered one at a time. Instead, the following discussion first considers one common human action: the moving of wild animals from one place to another (wildlife translocation), and then presents some thoughts on public support and acceptance of management actions undertaken to manage wild animal diseases.

TRANSLOCATION OF WILD ANIMALS

People move wild animals from one place to another for all kinds of reasons. Animals are moved to introduce new species, to restore extirpated species, to augment existing populations, to fulfil fantasies, to circumvent laws, etc.

The problem: Whenever animals are moved from one wild location to another, two potential disease problems always exist:

1) The animals being moved always carry disease-causing agents with them into the new environment. Thus, there always is a possibility that a new disease, harmful to the destination ecosystem, will be introduced with the new animals.

2) The animals being moved may be exposed to diseases in the destination ecosystem which will cause them harm and may make the translocation project a failure.

The scientific literature contains too many examples of both situations, sometimes occurring together in the same translocation. Major environmental disasters that have altered the ecology of whole regions have resulted from unintended introductions of disease with translocated animals. By such means, avian malaria, avian pox and the mosquito vector of both were brought, independently, to the Hawaiian Islands, and at least 25 species of native birds have become extinct as a result. Raccoons from Florida moved to West Virginia to be released for hunting included animals infected with the raccoon strain of rabies virus, until then restricted to the extreme southeast of the United States. The result has been an expanding epidemic of raccoon rabies that has swept through the major urban centers of the eastern United States and is about to enter Ontario, Quebec and New Brunswick. The cost to taxpayers of the countermeasures of post-exposure treatment of people bitten by raccoons and of other aspects of attempted disease containment have been astronomical. Rinderpest came to Africa, zebra mussels to the Great Lakes, and Brucellosis and Tuberculosis to Wood Buffalo National Park by means of animal translocation.

Exposure of translocated animals to harmful diseases in the new environment also is well-documented. Whooping Cranes brought eastward for captive propagation died of Eastern Equine Encephalitis, a disease that does not exist in their natural habitats. Caribou moved to the State of Maine from island of Newfoundland came from the only herd of animals in North America infected with the parasite *Elaphostrongylus cervi (rangiferi)*, the European "muscle worm", a parasite that can cause severe neurological disease in a wide range of native North American ungulates. They were moved into an environment infected with the parasite *Parelaphostrongylus tenuis*, the "brain worm" of White-tailed Deer, to which caribou are highly susceptible and which did cause fatal neurological disease in the translocated animals. It is hoped that the caribou died of brain worm before they were able to establish the European "muscle worm" on the North American continent.

2. Some Solutions:

Risk Assessment: Translocation should only be undertaken after close scrutiny of the relative risks and benefits of the translocation being considered.. A risk assessment should be conducted in every case. Guidelines for doing such risk assessments are available. For example, the Ontario Ministry of Agriculture, Food and Rural Affairs has made excellent guidelines available on the Internet at the following address:

http://www.gov.on.ca:80/OMAFRA/english/research/risk/as3.html

The benefits of a translocation must be shown to be worth the associated risks. When this is the case, everything possible should be done to reduce the disease risks associated with the proposed translocation. When this is not the case, the risk assessment provides a sound rationale for abandoning the proposed animal translocation.

Quarantine: A hedge against the unexpected is quarantine. Quarantine at the site of origin and at the destination should be part of every translocation. Quarantine periods should be as long as possible. For example, quarantine of deer moved from New Zealand to Australia included 6 months separation from other deer on pasture, 42 days of off-pasture quarantine in New Zealand and 100 days of tight quarantine in Australia. The main point of the quarantine was to ensure that no animals with the European "muscle worm" entered Australia. After a total of 100 days of quarantine and testing, larvae of the muscle worm were found in the feces of some animals, even though two previous tests had been negative. This example is a caution against short quarantine periods. Quarantine periods need to be as long as possible, and certainly somewhat longer than the maximum known incubation period of the infectious diseases of principle concern or of the period between the time an animal is infected and the time the infection can be detected by some kind of diagnostic test. This latter period can be many months for some important diseases. During quarantine, tests for known diseases of concern can be done and there also is the possibility that unexpected diseases also will become apparent. Quarantine is not fool-proof, but it is an important tool to reduce the disease risks associated with animal translocation.

Genes and Embryos: Sometimes the objectives of an animal translocation can be achieved by moving not whole animals but ova, semen or embryos. Disease-causing agents can be transported in these materials also, but such materials usually will contain many fewer kinds of infectious organisms than will a whole animal. There are many technical complications to the shipment and use of these materials, but, where such materials will meet objectives, they may be an attractive alternative to movement of whole animals.

SUPPORT AND COOPERATION FROM THE PUBLIC

Every wildlife management activity requires some form of compliance or approval from various segments of the public. Interventions to alter the course of diseases are no exception. Laws that are promulgated without the general acceptance of the people they affect often are not obeyed and are not enforceable. Conversely, public support for an intervention can go a very long way to ensure that the intervention is carried out. Thus, in the end, persuasion may succeed while compulsion often will fail. Persuasion, in its best form, means abundant explanation and information, planned educational campaigns, transparent processes to determine hierarchies of risks and values, and honesty at all points in the process.

Informing and Educating the Public

To achieve Compliance: Disease control efforts for Hydatid Disease, a disease of domestic animals that also is transmissible to humans, illustrates the importance of informing the public in a disease intervention where public compliance is key to success of the program. Hydatid disease is caused by a tapeworm (*Echinococcus granulosus*) that lives as an adult in the intestines of dogs and as a larvae in the viscera (lung, liver)of sheep and other ungulates. People suffer disease when they assume the role of the sheep in this disease cycle because they accidently ingest tapeworm eggs that are shed in dog feces. In Iceland in about 1860, about one of every six people was infected with Hydatid Disease. Prevention requires that dogs not be allowed to eat sheep viscera and that hygienic measures be employed to reduce the likelihood that humans are infected through contact with dogs. The disease was successfully eradicated from Iceland over a period of about 90 years, beginning with an informational pamphlet about the disease distributed to all Icelandic families in 1864. Information about the disease then was taught in all schools. This education campaign resulted in voluntary control measures that lowered the prevalence of infection in people from 15-22% to only 3% in about 25 years. Compulsory control was decreed in 1890 to a compliant and accepting public, and the disease was eradicated by the 1950's. New Zealand tried to control the same disease by a compulsory program that was not explained through public education or information campaigns. Compliance was low and there was no measurable effect on the prevalence of disease. A subsequent program in which public education was deployed as a key element resulted in wide-spread voluntary eradication efforts.

Compliance is essential to many disease control efforts. For example, hunters and fishermen will not discontinue their use of lead unless convinced that there is real harm resulting from their use of this toxic metal. Only an informed public can be expected to act in accordance with information. Not every education campaign is successful in achieving public support and compliance, but failure is more or less guaranteed when compliance is demanded of an un-informed public.

To reduce the impact of disease: Sometimes the disease problem that seems to require a disease intervention can be solved by simply modifying human behaviour, again largely through provision of information. Rabies is widespread in skunks in Saskatchewan. This wildlife disease and public health problem is managed by widely publicizing that skunks may be rabid and urging the vaccination of pets and livestock. It is not hard to convince the public to avoid skunks, and vaccination is promoted by municipal incentives (lower price for a dog license) and public education. Education campaigns can be targeted at specific groups or specific geographical areas, where risks are highest. The risk of several zoonotic diseases is high only at certain seasons and certain locations; people can be urged to avoid such places at those seasons. Hunters can be informed about trichinosis in bear or walrus meat and taught how to ensure that such meat is safe to eat. Campers can be informed about *Giardia* and how to avoid infection from drinking water. The diseases and their animal hosts can be left alone.. High risk areas can be closed to the public for various periods of time. The more that is known about the biology of a disease and its animal hosts, the more refined, focused and effective such intervention strategies can be.

Involving the Public in Wildlife Disease Issues

As a final comment, managers should not ignore the benefits to wildlife conservation of a public that feels some personal involvement with wildlife disease issues. Public outcries associated with events such as oil spills and botulism outbreaks testify to a public sympathy and empathy for wild animals and a desire to ensure their welfare. In the end, such people vote for wildlife conservation and support well-reasoned management programs. Substantial segments of the public are horrified by wildlife disasters and want to participate personally in remedial efforts such as attempts to rehabilitate wild animals. The direct benefits to wild populations of such activities may seem small, but it would be foolish to underestimate the indirect benefits to wildlife of this contact between an active and concerned public and real wildlife problems. Wise managers will see such public interest as a gift: an opportunity to educate the public and foster positive attitudes toward wildlife conservation and stewardship. It is in the long-term interests of wildlife management and conservation to welcome this interest and to forge partnerships with the organizations dedicated to wildlife rehabilitation and similar personal actions.

Management and intervention in diseases of wildlife

Assessing the effect of disease management (G. Wobeser)

Most of the methods that have been used for management of wildlife diseases are of unknown or unproven effectiveness

Assessing the effectiveness of a management technique should be planned at the same time that the objectives are defined and the methods are chosen. The goal should be adaptive management, in which mistakes can be recognized early and the most effective methods can be implemented.

- The first step in measuring the effectiveness of a program is to have clearly defined and measurable objectives, e.g.:

- to reduce the prevalence of lead shot in the gizzard of hunter-killed mallards to <5% by 2001.
- to have no more than 25 cases of rabies diagnosed in skunks each year
- to prevent introduction of *Fasciolodes magna* with translocated animals.
- to reduce mortality from botulism on Old Wives Lake to < 20,000 birds/year

- the second step is to establish the methods that will be used for assessing effectiveness before the program begins. This includes deciding:

- what criteria will be measured:
  - rate of infection?
  - total mortality?
  - effect on survival?
  - reported cases?
  - public satisfaction?
  - dollars spent?
- when should data be collected? (Before, during and after the program)

- what are the economics of disease management?

Costs are usually much easier to measure than the benefits, e.g, it is easy to calculate the costs involved in cleaning up carcasses during botulism outbreaks, but it is very difficult to determine the value of a duck that may be prevented from dying of botulism. Two methods have been used to assess the economics of management:

a) benefit:cost analysis: This method compares the value of the benefits to the costs. However, in addition to the difficulty in determining what a duck is worth, it is also very difficult to determine what the disease would look like without management. For instance, how many birds would have died without management vs. the number that died despite management? If this could be determined, then the question would be: Are X ducks "saved" worth Y$?

b) cost:effectiveness analysis: This method does not require putting a value on the benefits, only the costs are considered. The assumption is often made that some management will take place. In the case of botulism, the analysis might consider whether carcass cleanup, or some other management technique, will deliver the greatest return in terms of bird survival.

Funding spent on disease management in wild life often comes form the same pool as for other conservation activities; it is important that the best methods are used.

Management of Avian Botulism

Trent Bollinger

Avian botulism is currently the most important disease of wild waterfowl in North America. Since 1994 mortality on the Canadian prairies alone has been in the hundreds of thousands of birds per year and in each of 1997 and 1998 mortality on the Canadian prairies has been estimated at 1 million birds per year. Waterfowl managers consider these losses significant and spent approximately $900,000.00 in 1998 to pick up approximately 250,000 carcasses in an attempt to manage these outbreaks. In spite of these large losses and high costs it is still not clear whether current management strategies are effective in significantly reducing losses or even whether management is warranted.

Avian botulism is a form of food poisoning caused by the bacterium *Clostridium botulinum.* The bacterium occurs in two forms: a vegetative growth form and a spore or resting form. Vegetative growth only occurs when there is a high protein substrate, anaerobic conditions, and high temperatures. Decaying carcasses, especially vertebrate carcasses, provide excellent conditions for vegetative growth. Toxin is produced during vegetative growth and is released with lysis of the bacterial cell. Maggots feeding on decaying carcasses concentrate the toxin. Birds are exposed to the toxin when feeding on maggots and possibly other invertebrates which contain toxin. Once ingested, the toxin circulates in the bloodstream and diffuses to the peripheral nerves where it blocks release of the neurotransmitter acetylcholine preventing the transmission of nerve impulses to skeletal muscles. This leads to flaccid paralysis beginning with the legs and wings, and eventually involving the neck and respiratory muscles. Death can result from drowning, dehydration or respiratory failure. This production of additional carcasses provides substrate for further bacterial growth and toxin production. The production of toxin, which is due to the presence of a virus or bacteriophage infecting the bacterium, appears to have evolved to produce substrate for further replication. The concurrent production of proteins which complex with botulinal toxin to prevent its denaturation in the acid environment of the stomach, further supports the hypothesis that this bacterium-virus relationship has evolved to kill vertebrates in order to produce substrate for growth. The spore or resting form develops when substrate is diminished or environmental conditions are not conducive to vegetative growth. Spores are very resistant and withstand freezing and dessication. They persist in the sediments of lakes and marshes for years, and it is thought that ducks and birds frequently ingest spores which are available for vegetative growth when the bird dies.

Avian botulism can be managed at various levels or with a variety of different objectives. The disease can be managed at the level of the individual by treating affected birds with supportive care and antitoxin which can save over 75% of sick birds. Although this is highly effective for the individual bird it has little impact at the level of the population. The cost of collecting, treating, and holding sick birds may be a deterrent. This strategy is warranted only in cases where endangered or threatened bird species are effected, or in situations where there is public relations or educational value. Treatment by itself does not attempt to prevent the disease or remove the source of toxin; birds in the area will continue to die and those treated and released will be again at risk of exposure to the toxin.

Avian botulism can be also managed at the level of the outbreak, or local population, and this is where much of our current management effort takes place. Vertebrate carcasses are a well known source of botulinum toxin and the maggots that feed on decaying carcasses concentrate toxin and are readily eaten by waterbirds feeding on invertebrates. In theory removing carcasses before they decompose and produce maggots will prevent further poisoning of birds. Unfortunately, carcasses are difficult to find in heavily vegetated marshes where many of these botulism outbreaks occur and, even if all carcasses could be found during a search, it is often logistically impossible to search the entire area involved in a large outbreak within the 3 day time period during which maggots will develop on carcasses. Studies of efficiency of carcass pickup as measured by proportion of marked carcasses retrieved during avian botulism outbreaks at Pakowki Lake, Alberta and Whitewater Lake, Manitoba, in 1998, have shown pickup efficiencies of only 7% and 27%, respectively. These values reflect pickup efficiencies over entire lakes and averaged over the summer; pickup efficiencies are undoubtably higher in areas that are frequently and intensively searched by cleanup crews. Similar but more restricted studies at Stobart Lake and Whitford Lake, Alberta, in 1998, produced values of carcass cleanup efficiency of 21% and 16% respectively. These four values are similar to the 6% reported by Stutzenbaker et al. (1986) in Texas and the 32% reported by Cliplef and Wobeser (1993) in Saskatchewan. A low pickup efficiency is also reflected in carcass density estimates of approximately 45 carcasses per hectare in some areas on Whitewater Lake.

Managers and researchers are beginning to question the effectiveness of carcass pickup in reducing waterfowl losses to botulism, given the low efficiency of carcass pickup and the high carcass densities that remain in some areas of the marsh potentially utilized by susceptible birds. Reed and Rocke (1992) have reported a 4.5 times reduction in the mortality rates of penned birds on marshes when carcass densities within pens are reduced from 12 to 0 carcasses per hectare. However, the effect on mortality rates of current carcass pickup efforts, which frequently leave carcass densities well in excess of 12 carcasses per hectare, is unknown. Determining the effectiveness of cleanup is challenging due to difficulties in estimating populations at risk which are required, in conjunction with estimates of cumulative mortality, to estimate mortality rates. Poor visibility of birds, and potentially high turnover of birds on lakes, make estimates of populations at risk difficult. Monitoring of a known sub-population of birds by using radiotelemetry marked birds or monitoring birds in pen trials, similar to those used by Reed and Rocke (1992), appear to be the best methods of estimating mortality rates under different levels of carcass cleanup. Without these studies we will be unable to determine the cost-effectiveness of cleanup efforts.

Improving current levels of carcass pickup will require more manpower and equipment, and better deployment of resources. This firefighting approach to the management of botulism, by responding to outbreaks only after they have become established, will always be expensive. Prevention of the disease, or at least reducing the frequency and severity of botulism outbreaks, is likely to be more cost effective in the long-term. However, in order to prevent botulism we need to better understand the ecology of the disease and identify risk factors amenable to manipulation. Reducing mortality on marshes, and thereby reducing the number of carcasses available to trigger botulism outbreaks, is an obvious risk factor which can be manipulated. For example, moving a powerline responsible for waterfowl mortality has been reported to have reduced the occurrence of botulism. Similarly, blue-green algal poisoning of waterbirds is suspected to have precipitated, or at least exacerbated, some botulism outbreaks and work is underway to prove and better understand this relationship. Potentially, environmental parameters could be manipulated to reduce the frequency of blue-green algae blooms and therefore botulism outbreaks. Mortality of juvenile Franklin's gulls on colonies with heavy waterfowl use has been recently associated with some botulism outbreaks. Understanding causes of mortality in these colonies may lead to management strategies which will reduce Franklin's gull mortality and hence the frequency of botulism outbreaks.

Altering water levels and improving water quality has been used to manage botulism and is still used on some refuges. Managers at some locations feel these techniques have been effective while others feel they have had little or no effect. The effectiveness of these management techniques have not been systematically evaluated and what factors they alter in the ecology of botulism is not clearly understood. Modifications of basins to allow manipulation of water levels and water quality also are expensive, and these techniques must be demonstrated to be effective before they can be recommended for the control of botulism.

Finally, botulism can be managed at the level of the continental population as measured by either the fall flight or spring breeding population. Cumulative mortality due to botulism outbreaks at many sites during the summer may reduce populations of fall migrants. These losses are comparable to the hunter harvest during the fall flight. However, the effect botulism mortality has on subsequent breeding populations will depend on whether botulism mortality is shown to be additive or compensatory to other forms of mortality. If high botulism losses are compensated for by lower rates of other forms of mortality during the year, and vice versa, then managing botulism to reduce losses will ultimately have no effect on breeding populations. If managing for breeding populations is the objective, under this scenario, further botulism management programs are not warranted. Studies on how botulism affects annual survival rates, especially of species of concern (eg. northern pintails), are needed to address this question.

Botulism is a complex disease and its effects on waterfowl populations is poorly understood. Recent botulism losses have been high in some areas and as a consequence costs of management have also been high. Some progress has been made recently in assessing the efficiency of carcass cleanup as a method of managing botulism outbreaks. The results bring into question the effectiveness of this technique as it is currently implemented. Given the annual costs of botulism management, further studies are needed to determine how to better manage this disease and when, or if, management of this disease is warranted.

RABIES - the Alberta Approach

The general approach to rabies in Alberta is that "we don't have it .... and we don't want it. Note that this program parallels the attitude towards rats in the province! We currently believe we do not have rabies established (=enzootic) in free-ranging terrestrial wildlife and thus, field programs are aimed at eradication (as opposed to control) within the provincial boundaries. To understand this attitude we need to review the past.

The documented history of rabies in Alberta begins in the 1950s when the virus swept down from the Northwest Territories as a spillover from the enzootic infections in arctic foxes. Red fox and coyote were the primary vectors. Given that this appeared to be invasion of the virus into new geographic range and given the significant risk to human health and agricultural economics, the decision was made to strike fast and hard in order to eliminate the virus before it could establish in native wildlife. Alberta immediately established a Central Rabies Control Committee (CRCC) with representatives from public health, agriculture, wildlife, and municipal governments. All programs were guided by the underlying premise of eradicating the virus by population reduction of susceptible hosts and thus limiting transmission. The committee recommended programs that included massive predator control. Approximately 5000 miles of double traplines were activated around inhabited portions of the province. Additional animals were taken by poison, snares, and bounty. From 1952 to 1959, 70,000 foxes, 200,000 coyotes, 4500 wolves, 7500 lynx, 2000 bears, 500 skunks, and 64 cougar were destroyed. It is not possible to evaluate the specific effects of the programs or to separate them from the effects of the mortality caused by the virus. However, in the subsequent 12 year period (1957-1969) there were no reported cases of rabies in Alberta.

In the early 1970s, rabies again approached Alberta but this time from the east (Saskatchewan) and in skunks. Similar concerns were raised as earlier, but they were tempered by increased knowledge of the virus and its epizootiology. Programs were tailored to remove only skunks. Methods used included trapping (live and kill), strychnine poisoned eggs, and depopulation of winter skunk dens. A buffer zone (no-skunks-land) 18 mi wide, along the eastern border from Cold Lake to the US was established. Removal efforts were intense within this zone. While rabies became enzootic in Saskatchewan in the 1970s where population reduction was not implemented, reported cases in Alberta remained small and restricted only to the border region.

In 1979, rabies was identified in three skunks in southern Alberta. A program of 'radial-depopulation' was implemented. As above, the same tailored eradication methods were used to remove skunks within a 5 km radius of any confirmed rabid skunk. The size of the affected area initially increased as more rabid skunks were reported; however, the number of cases and size of affected area then declined steadily and petered out by 1986. Through the 1990s rabid skunks are reported sporadically within the vicinity of the Montana border and are considered spillover from enzootic areas to the south. Radial-depopulation remains the primary program of rabies control in Alberta.

review paper: Pybus, M.J. 1988. Rabies and rabies control in striped skunks (*Mephitis mephitis*) in three prairie regions of western North America. J. Wildlife Diseases 24: 434-449.

RABIES IN CANADA: A SYNOPSIS **M.J. Pybus: updated 01/97**

Vectors and Reservoirs

Rabies virus in Canada is maintained in populations of foxes, skunks, and bats. Exposure of humans commonly results from contact with dogs, cats, cattle, and occasionally, wildlife. All warm-blooded animals can be infected and essentially all infections are fatal.

Current Situation

The rabies problems in Canada originate with various wildlife species. Sporadic cases are reported in Arctic foxes and sled dogs in Northwest Territories; although many other cases probably are not reported. Rabies is not seen in terrestrial species in British Columbia. Alberta is "relatively" free of rabies. Striped skunks are the primary source of virus in southern Saskatchewan and Manitoba. The majority of reported cases in Canada occur in southeastern Ontario and southern Quebec where red fox play the leading role but striped skunks also are infected. A few rabid bats are reported annually in most provinces.

Approximately 80% of the reported diagnosed cases of rabies in Canada are in wildlife. The 20% in domestic species are a spillover from wildlife and involve roughly 30% each, dogs, cats, and cattle. Cases in humans are extremely rare.

Wildlife

In the Northwest Territories, "wild fox disease" was well known by locals but finally was identified as rabies in 1947 at Baker Lake. Soon after, the disease was confirmed in foxes and wolves. Mass vaccination of sled dogs in the affected area was carried out and the disease subsided, presenting no real threat to the southern part of the country until June 1952, when an outbreak starting in the Northwest Territories was reported in northern Alberta. Throughout the early 1950s, other outbreaks occurred at great distances from each other and were difficult to explain. Rabies was reported throughout Alberta and in the northern parts of British Columbia, Saskatchewan, and Manitoba, before it was brought under control. Rabies did not become established in western Canada.

In contrast, since the mid-fifties, rabies established in wildlife of the eastern and central provinces of Canada. After diagnosis of the disease in Arctic fox, it spread south and east via wildlife becoming established chiefly in red fox and striped skunk throughout the St Lawrence region. Infections have been reported in individuals of various wildlife species (bears, beaver, caribou, coyote, lynx, moose, mice, rabbits, wolves, deer, and weasels). Foxes and skunks remain the major disease reservoirs in the region.

Rabies invaded the prairie regions in 1959 as a movement northward out of North Dakota. Skunks acted as a reservoir, with some spillover into cattle, dogs, and cats. The disease reached eastern Saskatchewan by 1962/63 and western Saskatchewan by 1969. Control efforts by the Alberta Central Rabies Control Committee contributed to keeping the disease at bay and stopped its spread at the AB/SK border.

The most recent new outbreak of rabies involved sled dogs and red foxes in Newfoundland (early 1990s). The outbreak was unusual in that Newfoundland had no previous history of infections. It is hypothesized that infected animals migrated or were imported onto the island.

Very few human cases of rabies have been reported in Canada (less than 25 in recorded history). The terrestrial form of rabies appears to have low pathogenicity for humans. Recent fatal cases all involve bat strains of rabies.

Bat Rabies

Rabies is enzootic at low levels in bats throughout Canada, except the maritimes. It was first identified in big brown bats (*Eptesicus fuscus*) in British Columbia in 1957 but has since been reported in various species. Big brown bats remain the most commonly reported rabid bat. Rabies occurs in bats as individual isolated cases and appears to be independent of rabies in terrestrial species. The disease is common in vampire bats (*Desmodus spp.*) in Central and South America and may have been introduced into our northern insectivorous species by long-range migratory species such as silver-haired (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus cinereus*). Bat-source rabies has high pathogenicity in humans.

Control

Vaccination of pets, quarantine of suspect animals, and removal of feral dogs resulted in eradication of rabies in dogs and cats in the 1960s & 70s. However, a few pets are infected each year after encounters with rabid wildlife. Rabies in wildlife has proven harder to control. Programs involve reducing the local density of wildlife reservoirs below the threshold required for spread of the disease.

Early procedures included the use of trapping, poisoning, shooting, and gassing to reduce the number of predators in farming and urban areas, thereby protecting the lives of humans and livestock. Recent control programs have been targeted against specific wildlife vectors (skunks in Alberta, foxes in Ontario).

Canada's only major wildlife depopulation program, sponsored by the Alberta government, was initiated in 1953. Systematic eradication of predators resulted in at least 75,000 coyotes, 50,000 foxes, 4,200 wolves, 7,500 lynx, 1850 bears, 500 skunks, and 64 cougars killed in Alberta in a period of 1½ years. The province registered only 2 rabid animals (both domestic) between 1957 and 1969. In the 1970s and 80s, Alberta instituted rabies control programs directed against skunks. The programs have contributed towards limiting the distribution of the disease and preventing its establishment in free-ranging terrestrial wildlife. The programs are still in place.

Ontario is having tremendous success using vaccine-treated baits to limit rabies in red foxes. Recent results indicate disruption of the cyclic pattern of outbreaks and a significantly lower number of rabies cases in the province.

Rabies is one of only a handful of federal reportable diseases. As such, Agriculture Canada is the lead agency in all rabies surveillance and diagnostics. The program involves a reporting and diagnostic system, prompt investigation of all cases, notification and follow-up with public health and medical agencies, surveys of wildlife and dog populations, dog control measures, and free dog and cat vaccination clinics in affected areas.

Pre-exposure prophylaxis is available to persons in eminent danger of contacting potentially-infected animals (e.g. veterinarians, rabies biologists, bat biologists). However, anyone bitten by a known or suspected rabid animal is given post-exposure treatment consisting of an intra-muscular injection of rabies immune globulin and a series of up to 5 injections of human diploid vaccine. Current vaccines are safe and effective and provide prolonged protective immunity.

Concerns

Recent concerns regarding initiation of new outbreaks focus on translocation of various wild species. An on-going epizootic of rabies in the northeastern US was traced to translocation of infected racoons from the southeastern US. This outbreak has caused significant losses and economic expense to public health and wildlife agencies throughout the northeast. The outbreak has the potential to cross into Canada in the vicinity of Toronto and Hamilton - with high densities of human and racoon populations.

GIANT LIVER FLUKES

Giant liver fluke, *Fascioloides magna*, is a large (30X80mm) trematode (= flatworm) which occurs in the liver of wild and captive ungulates. The principal hosts are wapiti and white-tailed deer in western and eastern North America, respectively. Transmission is focused around wetlands as eggs hatch in water and immature stages develop only in aquatic snails. The larvae then leave the snails and encyst on vegetation in the water. Transmission occurs when contaminated vegetation is eaten by susceptible hosts. Young flukes migrate through the liver. When two flukes find each other they cease to migrate, providing an opportunity for the host to surround them in a fibrous capsule. The extent of damage to the liver differs with different hosts and may reflect inherent capabilities to limit infection. For example, intensity (=number of worms in an infected individual) and liver damage is minimal in whitetails, moderate in caribou, and extensive in wapiti. Although intensity remains low in moose, liver damage is extensive. In livestock, liver condemnation in cattle and fatal infections in domestic sheep have been reported.

The management implications from giant liver fluke are associated with the ease with which this parasite is translocated. Indeed, the initial descriptions of the fluke were based on specimens collected from wapiti that had been translocated from North America to Italy in the 1865. In fact, the current distribution of this fluke in Europe can be traced to direct movement of undetected infections in definitive hosts (wapiti, white-tailed deer, and fallow deer) and their subsequent management in small, often fenced, reserves or game parks. In North America, translocation of the fluke probably contributed to the current distribution of the parasite in Alberta, Ontario, Saskatchewan, and the southeastern USA. Translocation of giant liver fluke in captive cervids is of increasing concern. The extensive commercial movement of wapiti increases the risk to domestic and wild hosts in non-enzootic areas. The occurrence of flukes on game farms in eastern Montana and non-enzootic areas of Alberta has been documented.

The impact of *F. magna* on wild populations is not well documented. Although death of individuals may occur, there is little evidence of population control as a result of infection, although population declines of roe deer in Europe have been associated with fluke infections. In North America, moose are likely at greatest risk because of the severe liver damage. Low numbers in the Bow Valley (Alberta) and decreased calf survival (Minnesota) may be associated with fluke infection. More commonly, liver damage may predispose infected individuals to increased predation or loss of condition/productivity. As with many other parasites and diseases, conspicuous clinical signs and/or death are relatively easy to monitor. More subtle changes in infected hosts are more difficult to document. Recent work suggests that infected whitetails may have lower body weights and fewer antler points than uninfected deer of the same age and in the same population. Similarly, during the rut infected males lost significantly more weight than uninfected individuals. In Europe, decreased trophy value in red deer, roe deer, and fallow deer is a management concern.

There appears to be ample reason to be cautious in moving potentially infected hosts from enzootic to non-enzootic areas and for limiting infections within captive herds. Recommended management actions include anthelmintic treatment of wapiti and whitetails prior to translocation to non-enzootic areas as well as regular treatment and pasture management of game farm cervids and livestock.