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Infectious animal diseases: the wildlife/livestock interface

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Summary

The long-standing conflict between livestock owners and animal health authorities on the one hand, and wildlife conservationists on the other, is largely based on differing attitudes to controlling diseases of livestock which are associated with wildlife. The authors have attempted to highlight the fact that these disease problems are frequently bi-directional at the wildlife/livestock interface. The different categories of diseases involved are presented. A new dimension being faced by veterinary regulatory authorities is the spectre of emerging sylvatic foci of diseases, such as bovine tuberculosis, bovine brucellosis and possibly rinderpest; these diseases threaten to undermine national and international eradication schemes, which have been implemented and executed with significant success, and at great cost. Conversely, wildlife-based ecotourism world-wide has expanded rapidly over the past decade and is the source of lacking foreign revenue for many developing countries. Traditional subsistence farming is still the largest source of much-needed protein on some continents and this, together with the growth and hunger of historically disadvantaged communities for land, is forcing enterprises and communities with markedly different objectives and land-use practices to operate effectively in close proximity. Some land-users rely exclusively on wildlife, others on livestock and/or agronomy, while yet others need to combine these activities. The net result may be an expansion or intensification of the interface between wildlife and domestic livestock, which will require innovative control strategies that permit differing types of wildlife/livestock interaction, and that do not threaten the land-use options of neighbours, or the ability of a country to market animals and animal products profitably.

Keywords

Animal diseases – Diagnosis – Domestic animals – Management – Wildlife.

Introduction

It is beyond the scope of this chapter to discuss in any depth the many important animal diseases that cross-infect domestic and wild animals. Certain of these diseases are covered individually in sufficient detail in other chapters of this book. The objective of this chapter is to illustrate and discuss certain epidemiological concepts, observations and philosophies related to diseases crossing the interface between livestock and free-ranging wildlife, with emphasis on their detection, diagnosis and management. This interface may be linear, as along a fence line, or patchy – reflecting habitat preferences of a disease host. It may also be focal at a shared water point, or diffuse, where range and resources are shared – such as the case with the pastoral societies in the savannah ecosystems of Africa, and also in North America and the entire area of greater Europe where abundant populations of wild cervids and suids occur in many rural areas. Wherever this interface occurs, it should be regarded as a two-way street with the potential for the transmission of pathogens in either direction: from the wild to domestic animals, or from domestic animals to wildlife. In general, animal diseases which occur in any specific country or region, fall arbitrarily into one or more of three basic categories, namely:

– indigenous diseases, which are endemic to the country or region and are generally maintained in the livestock herds and/or free-ranging wildlife populations; this category also includes certain multi-species diseases that have an almost world-wide distribution, such as anthrax, rabies as well as certain enteropathogenic and anaerobic bacterial diseases

– alien/exotic diseases which have been introduced into a country or region, usually from the importation of infected animals or animal products

– emerging, re-emerging or truly novel diseases.

Animal health is an important issue for the agricultural industries as well as wildlife conservationists. Both groups have concerns as to what impact various diseases may have on their animals or populations, and each group is apprehensive about possible disease introduction and transmission at the interface. Despite the contrasting perspectives of livestock-based agriculture and wildlife conservationists on animal health issues, it must be stressed that there is substantial common ground. In much of sub-Saharan Africa, pastoralism has traditionally provided a viable land use and a relatively sustainable livelihood. Pastoralists have shown a remarkable degree of tolerance for wildlife with which they share the habitat, this resulting in significant populations of wild animals outside of officially 'protected areas'.

In developed countries, many of the same people are involved in both wildlife conservation and animal agriculture activities, and have an understanding of both sides of the controversial issues. Frequently, livestock are grazed on public land that is shared by wildlife. Livestock agriculturists and wildlife managers understand the concept and value of population health management as opposed to individual animal treatment and the concern for foreign animal disease introduction is mutual. In addition, both groups are competing against a 'tide of humanity' as human populations increase the demand for land and water resources. There is also unified concern regarding certain radical animal rights movements directed against consumptive use of both wild and domestic animals. Lastly, because the land base for much of wildlife production in developed countries is on private land, and much of private land is used for animal agriculture, many farming enterprises are indirectly beneficial to wildlife.

In Tables I, II and III, the epizootic potential (i.e. the potential for the specific disease to rapidly spread across vast expanses of territory, as well as international boundaries, causing large-scale damage in livestock or wildlife populations over a short period of time) is graded as major, moderate or limited. This epizootic potential is related to several epidemiological determinants, such as virulence and transmissibility of the causative organism, climatic and environmental factors, presence or absence of maintenance hosts, mode of transmission, presence or seasonal abundance of vectors, and presence of susceptible populations. Diseases with major epizootic potential are generally the highly contagious viral diseases (e.g. foot and mouth disease [FMD], rinderpest, Newcastle disease, African swine fever and classical swine fever), and these may have a significant impact on domestic livestock populations, agricultural-based export economies and wildlife. However, at the rural, subsistence farming and pastoral levels of the developing world, it is most frequently the vector-borne diseases, such as trypanosomosis, cowdriosis and theileriosis, which only have moderate or limited epizootic potential, that are the greatest disease obstacles to agricultural development and prosperity. Frequently, sympatric wildlife are resistant to these diseases, and may even be silent carriers of infection.

Wildlife-maintained (indigenous) diseases

Table I lists some of the more important diseases associated with wildlife that have been known to cause disease in domestic livestock. The single most important factor responsible for causing an outbreak of any one of these diseases is probably the direct or indirect (vector) contact of infected wild hosts or populations with susceptible domestic animals at the interface of their ranges; where mixing has occurred on common rangeland, or where other resources (water) are shared.

The epidemiological determinants, transmission and maintenance mechanisms have been studied in depth and are well understood for some of these diseases, as discussed below, while for others, such as cowdriosis, Rift Valley fever, lumpy skin disease, Newcastle disease and bluetongue, there are still many unanswered epidemiological questions.

Foot and mouth disease

In the case of FMD in Africa, the pivotal role played by the African buffalo (*Syncerus caffer*) as a sylvatic maintenance host was identified in the late 1960s (18, 19) and possible maintenance mechanisms of infection have been discussed (20, 64). Outside Africa, FMD is maintained mainly in domestic ruminants, particularly cattle, and wildlife occasionally become infected incidentally by 'spill over'.

African swine fever

With regard to African swine fever, the elegant studies by Plowright and co-workers (46, 47, 48) elucidated the maintenance host role of argasid ticks (*Ornithodorus moubata*), and the secondary role played by free-ranging wild porcines has also been described (49, 63).

Table I
Infectious diseases commonly transmitted from wildlife hosts to domestic livestock

Disease and causative agent	Direct transmission (D) Arthropod-borne (A)	Maintenance host	Domestic animals affected	Epizootic potential
Foot and mouth disease (aphthovirus)	D	African buffalo and cattle	Cattle, pigs, sheep and goats	Major
Trypanosomosis (*Trypanosoma* spp.)	A *Glossina* spp. and biting flies	Elephant, wild ruminants and wild suids	Cattle, horses, pigs, sheep, goats and dogs	Moderate
African swine fever (asfarvirus)	A and D *Ornithodorus* spp.	Argasid ticks, warthogs	Domestic pigs	Major
Theileriosis or Corridor disease (*Theileria parva* group)	A *Rhipicephalus* sp. ticks	African buffalo	Cattle	Moderate
Heartwater (*Cowdria ruminantium*)	A *Amblyomma* spp. ticks	Suspect buffalo, other artiodactyls, chelonians and gallinaceous birds	Cattle, sheep and goats	Moderate
African horse sickness (orbivirus)	A *Culicoides* midges	Zebra	Horses and donkeys	Moderate
Rift Valley fever (phlebovirus)	A *Aedes* and *Culex* spp.	Aedine mosquitoes	Sheep, goats, cattle, wild bovidae	Moderate
Bluetongue (orbivirus)	A *Culicoides* midges	Various artiodactyls (uncertain)	Sheep and cattle	Moderate
Lumpy skin disease (capripox)	Uncertain, probably insect-borne	Uncertain	Cattle	Moderate
Malignant catarrhal fever (Alcelaphine herpesvirus-1)	D (?)	Blue and black wildebeest	Cattle	Limited (seasonal)
Newcastle disease (paramyxovirus)	D	Wild birds, exotic pet birds	Poultry	Major
Classical swine fever (hog cholera)	D	Wild boar	Pigs	Major

Alcelaphine herpesvirus-1

Similarly, the important role played by wildebeest (*Connochaetes taurinus*) in the maintenance and seasonal shedding of Alcelaphine herpesvirus-1 has been elucidated (37, 44, 45, 52).

Trypanosomosis

Trypanosomosis is a very important disease of cattle, horses and dogs in Africa. It profoundly limits the distribution of livestock, and consequently severely hampers the development of that industry. Many species of antelope, buffalo, warthog (*Phaecochoerus aethiopicus*), hippopotamus (*Hippopotamus amphibius*), elephant (*Loxodonta africana*) and rhinoceros (*Diceros bicornis*) are capable of surviving in the tsetse fly belts, and frequently have significant infection rates with various *Trypanosoma* species, thus serving as excellent maintenance hosts for nagana (36). Ironically, many of the remaining and relatively pristine wildlife conservation areas in Africa owe their very existence and current status to the presence of this disease, which made those areas unsuitable for agricultural expansion.

Theileriosis

The biology and epidemiology of buffalo-associated theileriosis has been well studied, and it is now fairly generally accepted that *Theileria parva parva* is a cattle-adapted variant of *Theileria parva lawrenci* (24). Infection with this organism, which is generally 'silent' in buffalo, causes very high mortality rates in cattle, making farming of cattle in the presence of buffalo and a suitable vector, a hazardous undertaking (38). Cattle are generally 'dead-end' hosts, being unable to infect the intermediate ixodid tick hosts.

African horse sickness

In lowland areas of Africa, where winters are mild, African horse sickness is endemic in zebra (*Equus burchelli*) populations, and cycles throughout the year in the presence of certain persistent *Culicoides* spp. populations. The fact that zebra are non-seasonal breeders allows for susceptible individuals to enter the cycle at any time of the year (2), making zebras ideal maintenance hosts under these conditions.

Classical swine fever

In eastern and western Europe, classical swine fever virus has become endemic in populations of wild boar with sporadic spreading of the virus to domestic pigs either by direct contact or through unregulated swill feeding (32).

Multi-species diseases that occur on most continents

These diseases, which have an almost world-wide distribution, also occur in both wildlife and domestic livestock. Transmission can thus occur in both directions, although in

Table II
Multi-species diseases that occur on most continents

Disease and causative agent	Transmission mode	Maintenance hosts	Epizootic potential
Anthrax (*Bacillus anthracis*)	Food/water contamination Biting flies	Abiotic soil phase (spores)	Moderate to major
Rabies (lyssavirus)	Infectious saliva	Multiple	Moderate
Brucellosis (*Brucella* spp.)	Mucosal contamination	Various?	Moderate
Encephalomyocarditis (cardiovirus)	Faecal/urinary contamination of food/water	Rodents	Moderate
Epizootic haemorrhagic disease (orbivirus)	*Culicoides* vector	Unknown	Moderate

certain regions dominant role players have been identified. These diseases are generally cyclical in nature and the epidemic cycles appear to be related to population densities of one or more host species, as well as climatic factors. Uniquely, these diseases generally have a fatal outcome in both wildlife and domestic livestock, and are frequently zoonotic.

Anthrax

Anthrax is one of the oldest documented diseases, and the life-cycle *Bacillus anthracis* has both biotic and abiotic components. The abiotic component is the resistant dormant spore phase, which occurs in regions with predominantly alkaline soils with high calcium content. The biotic component is the exponential amplification phase, which takes place within the mammalian body, and appears to be the essential reproductive phase (11). Anthrax outbreaks have been documented in most domestic species, in the absence of any wildlife link. Similarly, localised to extensive outbreaks have occurred in wildlife populations with no livestock link. Large-scale outbreaks may cross this interface especially where domestic and non-domesticated species share range and resources in the environmental conditions that are associated with anthrax outbreaks. In recent years, outbreaks have been recorded in many species of different taxa in Africa and Asia, in reindeer (*Rangifer tarandus*) in Russia, in bison (*Bison bison*) in Canada and in white-tailed deer (*Odocoileus virginianus*) in the State of Texas. This disease in cattle can be controlled effectively by regular vaccination.

Rabies

Rabies is also an ancient disease and recognisable descriptions of this disease can be traced back to early Chinese, Egyptian, Greek and Roman records (67). In sub-Saharan Africa, sylvatic rabies has been diagnosed in 33 carnivorous species and 23 herbivorous species, with a regional variation of dominant epidemiological role players (59). In spite of this, by far the largest number of rabies cases reported in the developing world occur in domestic dogs and cattle, with 'spill-over' into other domestic species and man. In Africa, endemic rabies (caused by both viverid and canid biotypes) has been identified in certain communal burrow dwelling wildlife species, such as the yellow mongoose (*Cynictis penicillata*) and the bat-eared fox (*Otocyon megalotis*), as well as in jackals (*Canis mesomelas*). In Europe, the red fox (*Vulpes vulpes*) and raccoon dog (*Nyctereutes procyonoides*) are important contributors to the spread of disease. In North America, specific strains of rabies virus are geographically associated with wildlife species such as raccoons (*Procyon lotor*), red foxes, grey foxes (*Urocyon cinereoargenteus*), skunks (*Mephitis mephitis*) and coyotes (*Canis latrans*), as well as bats (*Tadarida braziliensis*) (55). Similarly, various bat lyssavirus biotypes have been identified from different parts of the world. Rabies infection may be transmitted in both directions where a wildlife/domestic animal interface exists.

Brucellosis

Brucellosis is also a disease that affects multiple species and occurs on most continents and even in marine ecosystems. Different species and bio-types of *Brucella* are found in the various global regions and in the phylogenetic taxa that they support. In sub-Saharan Africa, brucellosis, caused mainly by *Brucella abortus* biotype 1, has been described in several free-range ecosystems, infecting predominantly buffalo, hippopotamus and waterbuck (*Kobus ellipsiprymnus*) (10, 12, 15). Bovine brucellosis is believed to have been introduced into North American wildlife, such as the bison and wapiti (*Cervus elaphus*), by European domestic cattle (7). The disease now is endemic in these two species in the Greater Yellowstone Area in the northwestern United States of America (USA), although it has nearly been eradicated from domestic cattle in the country (66). This disease also occurs in some bison populations in Canada (61, 62). In Europe, certain biotypes of *Brucella suis* appear to cause most infections in wildlife. More recently, several previously unknown species of *Brucella* have been isolated from marine mammals.

Epizootic haemorrhagic disease of cervids

Epizootic haemorrhagic disease of cervids is caused by two serotypes of orbivirus, which are transmitted by biting midges of the genus *Culicoides*. Infection is generally sub-clinical in sheep and cattle, but severe disease with mortality occurs in cervids, particularly the white-tailed deer in North America (39).

Encephalomyocarditis

In the case of encephalomyocarditis infection, most available evidence points to rodents being the major reservoir and

Table III
Alien diseases that have infected wildlife and domestic livestock

Disease and causative agent	Direct transmission (D) Arthropod-borne (A)	Original maintenance host	Foreign hosts	Epizootic potential
Rinderpest (morbillivirus)	D	Cattle	Wild artiodactyls	Major
Bovine tuberculosis (*Mycobacterium bovis*)	D	Cattle	Buffalo, lechwe, bison, white-tailed deer, many other species (sporadic)	Moderate (slow)
Canine distemper (morbillivirus)	D	Domestic dogs	Wild dog, lion, jackals, hyaenas	Moderate
African swine fever (asfarvirus)	D (meat products) A	Wild porcines *Ornithodorus* spp.	Domestic pigs	Major
African horse sickness (orbivirus)	A	Zebras	Horses, donkeys	Moderate

maintenance host of this virus, which is a Picornavirus, and has an almost world-wide distribution. Slow endemic cycling of the virus in rodent populations appears to be the norm, with explosive epidemic outbreaks occurring during climatically driven rodent population escalations and peaks. 'Spill-over' infection with sporadic mortalities have been documented in domestic pigs and free-ranging elephants (16).

Alien/exotic diseases

Some of the best examples of this category are certain diseases historically alien to sub-Saharan Africa, that were probably introduced onto the African continent with the importation of domestic livestock from Europe and Asia during the colonial era. Indigenous African free-ranging mammals (within similar taxonomic groupings to these traditionally domesticated maintenance hosts) are generally immunologically naïve to these foreign agents. Significant morbidity and mortality may therefore be encountered in wildlife where contact with infected domestic animals occurs.

Rinderpest

A striking example was the rinderpest pandemic of 1889-1905 in sub-Saharan Africa, which is reputed to have been introduced into Eritrea from India by the Italian army in 1887/1888, or by a German military expedition that brought infected cattle from Aden and Bombay to the East African coast (22, 23). Much has been written (34) of the massive social, political and economic repercussions of the significant cattle mortalities caused by this disease as it spread progressively westwards and southwards. Countless wild artiodactyls also perished, with buffalo, tragelaphs (spiral horned antelope), wild suids and wildebeest being most severely affected and only relic populations survived in some areas (58). The decimation of both cattle and wildlife led to the apparent disappearance of tsetse flies (*Glossina* spp.) from certain areas, and may have contributed to certain wildlife distribution anomalies, such as the formation of isolated metapopulations of species such as sable antelope (*Hippotragus niger*), roan antelope (*Hippotragus equinus*), greater kudu (*Tragelaphus strepsiceros*) and nyala (*Tragelaphus angasi*).

Canine distemper

Canine distemper virus, another morbillivirus, was reported to have been introduced onto the African continent with domestic dogs. In the past decade, this disease has apparently crossed the species barrier in the Serengeti ecosystem, causing significant mortalities in lions (*Panthera leo*). It is estimated that 30% of the Serengeti lions died in this outbreak (51). The major population decline of the wild dog (*Lycaon pictus*) in this ecosystem, may in part be attributed to this disease (1). In North America, canine distemper is an important disease of raccoons, grey foxes and coyotes (68).

Bovine tuberculosis

Bovine tuberculosis has become a major disease problem in wildlife in many parts of the world. In Africa, this disease was most probably introduced with imported dairy and *Bos taurus*-type beef cattle during the colonial era. This disease has now spread to and has become endemic in several buffalo populations in South Africa (3, 4), and Uganda (17, 70, 71), as well as in a Kafue lechwe (*Kobus leche kafuensis*) population in Zambia (14). Buffalo and lechwe have become true sylvatic maintenance hosts of this mycobacterial disease, and sporadic 'spill-over' of infection has been documented in greater kudu (5, 29, 43, 65), common duiker (*Sylvicapra grimmia*) (43), chacma baboon (*Papio ursinus*) (28), olive baboon (*Papio anubis*) (60), lion, cheetah (*Acinonyx jubatus*) (26), leopard (*Panthera pardus*), warthog (70), bushpig (*Potamochoerus larvatus*), hyaena (*Crocuta crocuta*) and common genet (*Genetta genetta*). The long-term effects of this chronic progressive disease on African wildlife host populations at sustained high prevalence rates is unknown, but preliminary evidence suggests that it may negatively affect population dynamics or structure in buffalo and lion.

In New Zealand, brush-tailed possums and ferrets have become sylvatic maintenance hosts (13, 25, 33, 50) and in the United Kingdom (UK) and Ireland, badgers maintain the infection

(9, 40). In Australia, bovine tuberculosis infection was a major problem in feral water buffalo and feral pigs in the Northern territories (21). In Canada, bison in and around Wood Buffalo Park are infected (60, 62). In Hawaii, *Mycobacterium bovis* infection was found in axis deer and feral pigs (53). In the State of Michigan in the north central USA, endemic tuberculosis is now found in white-tailed deer in several counties. It is believed that tuberculosis was introduced into deer via infected cattle prior to control of the disease in the domestic species (54). In central and eastern Europe, *M. bovis* infection occurs in wild boars.

In Europe, several exotic diseases have unwittingly been introduced from Africa.

African swine fever

Introduced into Portugal in the early 1960s, African swine fever was then repeatedly spread from the Iberian Peninsula by illicit movements of infected pigs, or more commonly infected pig products, and invaded France (1964, 1967, 1977), Madeira (1965, 1974, 1976), Italy (1967, 1980), Malta (1978), Sardinia (1978), Belgium (1985) and most recently Holland (1986). All these extensions were eliminated with the exception of that in Sardinia, which has remained infected until the present day (49).

Outside Europe, African swine fever also spread to Cuba, Haiti, Brazil and the Dominican Republic.

African horse sickness

African horse sickness also spread from sub-Saharan Africa to Saudi Arabia and Spain (9). This latter spread into the Iberian Peninsula appeared to have been related to the importation of zebra from Namibia.

West Nile virus

In the USA, a recent example was the introduction of West Nile virus into the northeastern states from either Africa or the Mediterranean region. This virus infected a wide spectrum of avian species, and although the initial outbreak was in New York, infection has now spread to several neighbouring states (57).

Emerging diseases

So-called emerging diseases include recently detected diseases, diseases that have recently crossed the species barrier, and finally, truly novel diseases.

Examples of recently detected diseases are parafilariasis in buffalo (27) and feline immunodeficiency virus infection in free-ranging large felids (42, 56).

Examples of diseases that have recently crossed the species barrier are canine distemper in free-ranging lions (51), encephalomyocarditis in free-ranging African elephant (16) and bovine tuberculosis in free-ranging carnivores (3, 30).

An example of a truly novel disease is chronic wasting disease (a transmissible spongiform encephalopathy) in cervids in the western USA (35, 41, 69).

Disease transmission: the wildlife/livestock interface

The transmission of infection between wildlife and domestic livestock may occur in several different ways which are dependent on both spatial and temporal elements. These elements may vary, depending on the infectious agents involved and /or the presence or necessity of a biological or mechanical vector in the epidemiological cycle.

One important factor responsible for the cause of outbreaks of any one of the above-mentioned diseases is the direct or indirect (vector) contact of infected animals or populations (wild or domestic) with susceptible populations at the interface of their ranges. In this situation, most of the potential transmission mechanisms may become operative and these include the following:

– aerosols, contamination of feed water and range (e.g. FMD, rinderpest, bovine tuberculosis, brucellosis, canine distemper, anthrax, bovine malignant catarrhal fever [BMC] and encephalomyocarditis)

– a flightless vector (e.g. tick-borne protozoal and rickettsial diseases, and African swine fever)

– a winged vector, be it biological transmission (e.g. trypanosomosis, orbivirus and phlebovirus infections, or mechanical transmission as in anthrax, parafilariasis and possibly BMC).

In the situation where a natural (e.g. river or mountain range) or man-made (e.g. fence) barrier exists between wildlife and domestic livestock populations, then winged vectors, both arthropod and avian (vultures) become important transmission modes.

Other elements that affect transmission are generally related to seasonal/climatic cycles and fluctuations which affect both animal numbers and distribution as well as vector abundance. Thus vector-borne infections generally increase during periods of normal and above-normal rainfall, as vector numbers increase (e.g. Rift Valley fever and African horse sickness), but become less active during dry spells/cycles, which do not favour vector amplification. In contrast, close contact and some water-related infections increase during the dry seasons/cycles, when animals concentrate at remaining permanent water points (e.g. epizootic FMD and anthrax), and become less active when animals disperse during wet periods, when water availability is no longer a factor. Droughts are also generally linked to malnutrition, and through hypoproteinaemia and hypovitaminoses, immunocompetence may be compromised.

The presence of one or more maintenance hosts in an ecosystem is epidemiologically significant, and is responsible for the long term persistence of infection in a given ecosystem. Taxonomic grouping, social organisation and behaviour, and population densities usually determine the maintenance host potential of a given species for a specific disease. Incidental hosts can rarely perpetuate infection for any significant period of time in the absence of a maintenance host. Over-wintering hosts and strategies appear to be important in the more temperate climates, particularly in respect of arbovirus infections.

One of the most important factors in disease transmission between livestock and wildlife is the creation of new interfaces, usually as a consequence of pastoral transhumance, regional conflicts or political instability, in the developing world, and irresponsible translocation or introductions of animals, in the developed world.

Disease detection and diagnosis at the wildlife/livestock interface

The responsibility for disease surveillance in domestic livestock generally rests with the veterinary regulatory authorities of a given country, and the surveillance techniques used include passive reporting, farm inspections, problem investigations, abattoir surveys, serological surveys and dedicated testing for specific disease eradication schemes. Unfortunately, legal frameworks and responsibilities (including financial responsibilities) for wildlife disease investigation and reporting are not clear in many countries and, in addition, free-ranging wildlife do not easily lend themselves to manipulation.

Surveillance techniques should thus be structured to maximize information gained from the limited availability of carcasses or captured animals. This will require the development of public (veterinary and wildlife management authorities), private- and community-based approaches. Examples of various techniques that can be applied are as follows:

– active investigation of any reports of abnormal clinical signs, mortalities or sustained increase in vulture activity in a given geographical area. Where anthrax is suspected, lay staff can be trained to collect blood smears and fill in simple data sheets

– diagnostic necropsies on all carcasses that become available on an ad hoc basis. Innovative initiatives, such as collection of road kills or examining hunter kills, can substantially increase the number of carcasses examined

– veterinary and veterinary public health inspections at all lethal wildlife population management (culling) operations, as well as livestock slaughter premises in the interface area

– veterinary supervision of protected area systems for disease monitoring

– veterinary examination of all animals captured for any reason at all, including translocation, clinical assistance, fitting radio transmitters, or removal of problem animals

– veterinary supervision at all wild animal holding facilities and game sales

– dedicated sero-surveys are also an excellent, though expensive, surveillance technique. The value of serum and tissue banks for retrospective studies cannot be over-emphasised.

In all the above-mentioned 'hands-on' situations, sample collection, including body fluids, tissues and excretions should be maximised.

Additional indirect techniques for disease surveillance may include the following:

– rodent trapping for serological surveys (arbo- and cardioviruses) or disease agent isolation

– vector trapping for distribution studies (e.g. *Glossina* spp. and *Culicoides* spp.) or virus isolation (e.g. orbivirus and phlebovirus) and xenodiagnosis.

The confirmation of the aetiological cause of morbidity or mortality in both wild and domestic animals is paramount. Once the aetiological agent has been positively identified, then decisions can be made with regard to appropriate disease management, where necessary.

Diagnostic tests are available for the majority of diseases found in domestic animals. The sensitivity and specificity of these diagnostic tests varies considerably, so that certain tests can be considered confirmational in a single animal (e.g. rabies fluorescent antibody or immunoperoxidase tests), whereas others should only be considered herd tests (e.g. the bovine tuberculosis comparative intradermal tuberculin test or the blood-based gamma interferon test). Repeat testing to determine sero-stability is also important, particularly in a closed herd or quarantine situation. Serial sampling may also assist in determining baseline levels and trends, and is also valuable for detecting parasitic conditions where intermittent shedding of ova or oocysts occur. Pooled sampling may also be used to increase diagnostic sensitivity in a group of animals that are intermittent shedders.

With regard to disease testing of wild animals, one cannot assume that tests that have been developed for domestic livestock are equally sensitive or specific in their wildlife counterparts. Many of the current tests still need to be validated in wildlife.

Another important factor is to ensure that testing certain species for a specific disease is appropriate. For example, it is probably inappropriate to test perissodactyls, such as rhinoceros and zebra, for FMD or rinderpest.

Diagnostic tests, where the aetiological organism is isolated by culture, should generally have similar sensitivities for most species. Likewise, with few exceptions, histopathology with specific staining techniques should have similar sensitivities for most species. It is mainly with regard to serological tests and other *in vitro* blood-based tests that varying sensitivities and specificities are found. Certain species idiosyncrasies also occur – for instance the serum of most African elephants is anti-complementary. In addition, tuberculin skin tests have low specificity in pachyderms, with many false-positive reactions.

Disease management at the wildlife/livestock interface

In general, control of diseases of moderate or limited epizootic potential is best addressed at the local level, with the assistance of veterinarians and wildlife experts with detailed knowledge of the relevant epidemiological and ecological determinants. For infections capable of causing transboundary epizootics, control needs to be co-ordinated at both national and international levels.

While short and medium term disease control and long-term eradication goals can and have been attained in domestic livestock using judicious vaccination programmes, vector control and test-and-slaughter policies, these options and techniques are frequently impractical or difficult to execute, and may be culturally or morally unacceptable in free-ranging pastoral livestock and wildlife populations.

When dealing with the threat of certain endemic African diseases such as FMD, African swine fever and theileriosis, the containment option has frequently given the best results. This option is usually effected by means of control zones/areas, game-proof fences, cordons and movement control, which separate the wildlife from domestic livestock, thus effectively blocking the interface. This option is generally used in countries with an advanced land use policy and where nomadic pastoralism does not occur.

When dealing with endemic arthropod-borne infections such as trypanosomosis, epizootic haemorrhagic disease, African horse sickness, Rift Valley fever and bluetongue, containment is less likely to succeed and vaccination and vector control may be included to reduce transmission.

With regard to alien/exotic diseases that threaten free-ranging wildlife populations, such as bovine tuberculosis, rinderpest and canine distemper, containment and control can best be effected by addressing the disease in the domestic host by test-and-slaughter and mass vaccination, respectively. In addition, prevention of contact between infected domestic animals and wildlife is desirable, but unfortunately not always feasible. In these situations, improving the delivery of animal health services (e.g. through vaccination of domestic livestock sharing range with wildlife, and/or adjacent to conservation areas), would probably be most beneficial if a suitable vaccine is available. For example, rinderpest control has been based on vaccination and the benefits of eradication are economically significant even without calculating the benefits to wildlife populations. There is the additional benefit that resident wild animals also act as sentinels, providing spatial and temporal (based on age stratification) data to facilitate rinderpest surveillance and identify existing or new foci of infection (31).

With regard to the multi-species diseases, such as anthrax and rabies, many ecologists will argue that these diseases are also endemic and part of the greater ecosystem, and because they function as natural population regulators, they should not be controlled. On the other hand, both these diseases also affect domestic animals, and have significant zoonotic potential. There are now few, if any, ecosystems which are isolated from humans and domestic animals, and modern societies will no longer accept the impact of disease as natural. This renders the *laissez faire* argument redundant. For these reasons, control of anthrax outbreaks in wildlife have been attempted, using various techniques including burning/burying of carcasses, veld burning, waterhole disinfection and remote vaccination by means of disposable darts or bio-bullets. These attempts have met with varying success. On the other hand, mass vaccination of foxes against rabies in Europe, using oral bait techniques, has been highly effective and successful. Central to the reduction in livestock losses and human exposures during anthrax or rabies outbreaks in wildlife, are large-scale public awareness campaigns, and mass vaccination of domestic animals.

Where an alien disease has become established in a free-ranging wildlife population, the situation is serious, control options are limited and frequently contentious or unpopular. The bovine tuberculosis situations in buffalo and lechwe in Africa, badgers in the UK, bison in Canada, and white-tailed deer in the USA, are good examples.

When dealing with an alien disease that has become endemic in free-ranging wildlife, the following factors must be taken into consideration, and the necessary information must be gathered, prior to deciding on possible containment or control options:

– determine the spatial distribution of the disease

– identify the major maintenance host(s)

– determine the prevalence rate in maintenance host(s)

– identify 'spill-over' hosts

– identify transmission modes

– identify the original source of infection

– identify human activities that may increase transmission rates such as baiting and winter-feeding

– evaluate ante-mortem diagnostic tests in wildlife

– explore the vaccine option

– identify any natural physical barriers to movement of hosts or disease, such as large mountain ranges, large bodies of water, deserts or impenetrable forests.

It should be remembered that lethal control measures are highly contentious in indigenous wildlife, but generally enjoy significant public support when feral or alien species are the maintenance hosts (e.g. tuberculosis in possums in New Zealand and water buffalo in Australia).

With this information available, containment/control options may be evaluated.

These options may include the following:

– containment (short- to medium-term) by the creation of barriers between infected and non-infected populations (e.g. double fences or maintenance host/depopulation zones)

– control (medium-term) may require population management when dealing with density-dependent diseases. This may entail depopulation of high prevalence herds, and test and slaughter in low prevalence herds to reduce overall prevalence and environmental contamination when dealing with herd animals. The advent of a suitable, effective and safe vaccine would also be a valuable and popular control tool. Where appropriate, vector control may be employed

– eradication is a long-term objective and may require the continued application of the above containment and control measures, augmented by major depopulation of persistent foci and problem herds.

Discussion

In many areas of the world, it is increasingly apparent that ecotourism based on wildlife is potentially more profitable than livestock raising, the consequences being that more and more land-owners are deserting livestock production. This sometimes conflicts with the policies of developing countries, which place a premium on agricultural and industrial development, and has led to the criticism that wildlife is held in higher regard than people. Furthermore, there is a trend for game farmers in some areas to pool their resources and to form larger wildlife conservancies that can be more effectively managed so as to maximise sustainable profitability from ecotourism. These enterprises require a wide diversity of species and adequate populations for visitor viewing, which sometimes requires the large-scale translocation of wildlife with its attendant disease risk problems. It must be appreciated that the translocation of any animal is in fact the translocation of a 'biological package' consisting of the host and its attendant macro- and micro-parasites. Furthermore, it is important to realise that once released into a free-ranging system, such animals are difficult, if not impossible, to retrieve. Thus, quarantine, disease screening, deworming and dipping are essential requirements for responsible translocation of wildlife. Disease hazard identification in founder populations, followed by risk assessment and risk management strategies thus form the backbone of regulatory disease control on a national and international level. In this context, the zoosanitary implications of animal movements should always be evaluated by all parties.

The expansion and entrenchment of wildlife on both private ranches and provincial, national and international conservation areas has obvious benefits for the preservation of ecosystems, as well as promotion of tourism with its associated financial 'spin offs'. It should however be appreciated that this development will also probably extend and possibly intensify the interface between free-ranging wildlife and domestic livestock, and the potential for 'cross over' of diseases may increase. There is therefore an urgent need for innovative animal disease control policies that do not limit land-use options, and proactive thinking and planning will be necessary to prevent the development of serious animal disease events. For example, in developing countries, it may possibly be advantageous and appropriate to embark on programmes of selection and breeding of genetically trypanotolerant cattle or African swine fever-resistant pigs to address these disease problems in subsistence rural communities. Another innovative strategy is to select or breed wildlife that are free of certain diseases, and to use these animals for stocking of new areas, or translocation exercises. Another good example of this strategy is the breeding of 'disease-free' buffalo in South Africa (6).

■

Maladies animales infectieuses : interface entre animaux sauvages et animaux d'élevage

R.G. Bengis, R.A. Kock & J. Fischer

Résumé

Le conflit qui oppose depuis longtemps les éleveurs et les autorités zoosanitaires, d'une part, aux protecteurs de la faune sauvage, d'autre part, tient en grande partie à leur conception différente de la lutte contre les maladies associées à la faune sauvage et affectant les animaux d'élevage. Les auteurs s'emploient à démontrer que ces problèmes sanitaires ont un caractère bidirectionnel et concernent l'interface entre animaux sauvages et animaux d'élevage. Les différentes catégories de maladies en cause sont décrites. Les services vétérinaires officiels sont désormais confrontés à l'apparition de foyers sylvatiques de maladies animales telles que la tuberculose bovine, la brucellose bovine et, peut-être, la peste bovine ; ces maladies menacent de compromettre la réussite des coûteux programmes d'éradication mis en œuvre aux niveaux national et international et qui donnent jusqu'à présent d'excellents résultats. Par ailleurs, l'écotourisme ciblant la faune sauvage s'est considérablement développé dans le monde ces dix dernières années, constituant une source appréciable de devises pour nombre de pays en développement. Compte tenu du fait que l'élevage de subsistance traditionnel reste la principale source de protéines dans plusieurs continents, compte tenu également de la croissance démographique et du problème de sécurité alimentaire qui reste toujours menaçant pour certaines communautés historiquement pauvres en terres, les entreprises et les collectivités concernées se voient contraintes de rechercher des solutions efficaces dans un contexte de contiguïté géographique, bien que leurs objectifs et pratiques en matière d'utilisation des sols soient par ailleurs radicalement différents. Certains exploitants se consacrent exclusivement à la faune sauvage, d'autres à l'élevage et/ou à l'agriculture tandis que d'autres encore sont amenés à associer ces différentes activités. Il en résulte un développement ou un renforcement de l'interface entre animaux sauvages et animaux domestiques, qui appellent la mise en œuvre de stratégies de prophylaxie novatrices recourant à différentes interactions entre la faune sauvage et les animaux d'élevage sans pour autant compromettre les choix des communautés voisines en termes d'utilisation des terres ni l'aptitude d'un pays à commercialiser ses animaux et ses produits d'origine animale avec profit.

Mots-clés

Animaux domestiques – Diagnostic – Faune sauvage – Gestion – Maladies animales.

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Enfermedades animales infecciosas: la zona de contacto entre fauna salvaje y animales domésticos

R.G. Bengis, R.A. Kock & J. Fischer

Resumen

El persistente conflicto entre ganaderos y autoridades zoosanitarias por un lado y defensores de la fauna salvaje por el otro obedece en buena parte a discrepancias sobre el control de enfermedades del ganado asociadas a los animales salvajes. Los autores intentan poner de relieve el carácter bidireccional que suelen tener esos problemas sanitarios en las zonas de contacto entre fauna

salvaje y animales domésticos, y presentan después las distintas clases de enfermedades problemáticas. Los organismos reguladores veterinarios deben hacer frente a una nueva dimensión del problema: el espectro de nuevos focos salvajes de enfermedades como la tuberculosis y la brucelosis bovinas, así como, seguramente, la peste bovina. Estas enfermedades amenazan con malograr planes nacionales o internacionales de erradicación tan fructíferos como extremadamente caros. Pero por otro lado, en el último decenio ha crecido con rapidez en todo el mundo el turismo ecológico centrado en la fauna salvaje, hasta convertirse en una preciada fuente de divisas para muchos países en desarrollo. El hecho de que la ganadería tradicional de subsistencia siga siendo en ciertos continentes la fuente principal e indispensable de proteínas, aunado al crecimiento demográfico y el problema de abastecimiento en alimentos que afecta a comunidades tradicionalmente pobres en tierras, está llevando a empresas y comunidades que tienen objetivos y métodos de labor marcadamente distintos a trabajar de manera eficaz en condiciones de contigüidad geográfica. Algunos de los explotadores de las tierras viven exclusivamente de la fauna salvaje, otros del ganado y/o la agricultura y otros tienen que combinar todas esas actividades. Todo ello puede desembocar en el crecimiento o la intensificación de la zona de contacto entre animales salvajes y domésticos, lo que exigirá estrategias de control innovadoras, que admitan distintos tipos de interacción entre ambas clases de animales y no pongan en peligro ni los modos de explotación de los vecinos ni las posibilidades del país de obtener beneficios del comercio de animales y productos pecuarios.

Palabras clave
Animales domésticos – Diagnóstico – Enfermedades animales – Fauna salvaje – Gestión.

■

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