Chapter 1
Introduction

In this chapter you will find:

A general introduction to animal diseases in wetlands – what they are and why they are a growing problem.

A summary of the impacts of wetland disease on biodiversity and the environment, livestock and human health and its economic implications.

The scope, aim and objectives of this Manual.

Chapter contents

1.1 The state of wetlands

Wetlands are the most diverse and among the most productive ecosystems on earth. They support a high diversity and abundance of plants, birds, mammals, reptiles, amphibians, fish and invertebrates, as well as the millions of people who rely directly on wetlands for their health, livelihoods, welfare and safety. In addition, wetlands provide tremendous economic benefits, for example:

- Water supply (quantity and quality);
- Fisheries (over two thirds of the world's fish harvest is linked to the health of coastal and inland wetland areas);
- Agriculture, through the maintenance of water tables and nutrient retention in floodplains;
- Timber production;
- Energy resources, such as peat and plant matter;
- Wildlife resources;
- Transport; and
- Recreation and tourism opportunities.

Yet, in spite of their obvious importance, wetlands continue to be among the world's most threatened ecosystems, owing mainly to ongoing drainage, conversion, pollution and over-exploitation of their resources.

Many of these impacts have obvious and immediate effects, such as drainage and conversion. However, some effects, such as those from chemical pollutants, waste or excess nutrients, are more insidious, and their impacts may be more difficult to understand and quantify. One aspect which is increasingly being recognised by wetland scientists and managers as an important threat is disease. Diseases affecting wetlands have increased in both frequency and severity within the last few decades and have had major impacts on human health, livelihoods, domestic animal health and biodiversity. Yet, considering the underlying causes of disease emergence it is surprising that disease prevention is often under-recognised in management plans and actions.

1.2 What is disease?

Disease is a natural component of population ecology and ecosystems and is one mechanism by which population numbers are regulated. However, anthropogenic activities can often create novel disease problems or increases in prevalence and frequency of existing disease tipping a 'balanced' system into one where losses are increased.

DEFINITIONS 1-1. Health and disease	
Health:	a positive state of physical and mental well-being.
Disease:	a departure from a state of health; any impairment to health resulting in physiological dysfunction; "dis-ease" means literally a departure from a state of ease.

An important concept in understanding the impact of diseases on a host is that whilst diseases may cause death and/or morbidity, they may also affect the host in other ways, such as, reducing reproductive productivity and increasing susceptibility to other diseases or predation. Overall, it is important to understand that the effects of disease are often much more subtle than life or death but nonetheless can have wide ranging consequences for populations.

Figure 1-1. Canada goose *Branta canadensis* family in Greenland. Disease affects mortality and productivity, the latter in a variety of ways - a disease may delay growth so shortening the overall reproductive lifespan; the diseased host may be less able to find a mate and produce fewer young; the young may be less fit; and the diseased parent may be less fit at provisioning young and parenting effectively (*WWT*).

Types of disease

Diseases of wetlands include a wide-variety of disease types including:

Infectious:	Disease due to the presence of an infectious agent that is capable of being transmitted to another host, *e.g.* avian influenza and brucellosis. This includes 'zoonotic' disease [►**Definitions 1-2. Zoonosis and related terms**].
Toxic:	Disease caused by a toxin or poison, *e.g.* avian botulism and lead poisoning.
Nutritional:	Disease caused by nutritional imbalance or deficiency, *e.g.* starvation and metabolic bone disease.
Traumatic:	Disease caused by physical injury, *e.g.* following a hard structure collision, and electrocution.
Immunological:	Disease caused by disruption or abnormal function of the immune system, *e.g.* allergy.
Developmental:	Disease that interrupts normal development in growing animals. A developmental disease may affect a specific part of the body or affect multiple systems.
Congenital/ genetic:	Disease that is inherited genetically or caused by loss in heterozygosity, *e.g.* infertility due to the consequences of in-breeding.
Neoplastic:	Disease caused by abnormal new growth of tissue, a tumour, *e.g.* cancer.

Much of the focus of this Manual is biotic diseases: those that are caused by a living agent, such as a bacterium, fungus, virus, or protist. This category includes both infectious diseases (those that can be transmitted between host organisms) and some non-infectious diseases (those that cannot be transmitted between host organisms). An example of an infectious biotic disease is brucellosis: caused by bacteria of the genus *Brucella* and spread between animals by direct contact with contaminated body fluids. An example of a non-infectious biotic disease is avian botulism: toxins released by the bacterium *Clostridium botulinum* cause a non-infectious disease in organisms that consume it.

Other forms of disease that impact wetlands may be considered abiotic diseases: those that are caused by non-living, environmental agents, such as, toxic chemicals, heavy metals, extreme temperatures, UV radiation and nutrient imbalance. Abiotic diseases are non-infectious. An example of an abiotic disease is lead poisoning: caused by exposure to the heavy metal lead [►Table 1-1].

DEFINITIONS 1-2. Zoonosis and related terms

Zoonosis: a disease primarily of vertebrate animals that can be naturally transmitted to humans (in some instances, by a vector) and *vice versa*.

Zoonoses: plural.

Zoonotic: adjective.

A non-zoonotic disease cannot be transmitted naturally between animals and humans.

Table 1-1. Examples of how diseases can be categorised according to their ability to be transmitted between organisms, causal agents and ability to infect humans.

	Biotic *Caused by a living agent, such as a bacterium, fungus, virus or protist*	**Abiotic** *Caused by an environmental agent, such as chemicals or UV radiation*
Infectious *Capable of being transmitted between host organisms*	**Zoonotic** *Can be transmitted to humans* ▪ Brucellosis ▪ Avian influenza **Non-zoonotic** *Cannot be transmitted to humans* ▪ Chytridiomycosis ▪ Duck virus enteritis	
Non-infectious *Not capable of being transmitted between host organisms and including toxic disease, nutritional disease, trauma, genetic diseases, developmental disease etc.*	▪ Avian botulism ▪ Harmful algal blooms ▪ Aflatoxicosis	▪ Lead poisoning ▪ Trauma following hard structure collision

1.3 Wetlands and the threat of disease

Well functioning wetlands with well managed livestock with little interface with well managed wildlife should provide human wetland dwellers with the ideal healthy environment in which to thrive. Yet wetlands are at particular risk of emerging and re-emerging diseases due to a number of specific attributes:

- Their association with high population densities of people, agriculture including aquaculture, and industry;
- Pollution from the above;
- Sites providing interfaces between livestock, wildlife and people;
- Having been subject to substantial habitat modification;
- Sites rarely being isolated, instead usually being connected within catchments;
- Trade;
- The high diversity of host taxa;
- The high proportions of invasive alien species with their associated parasites; and
- The specific impacts of climate change on wetlands, their hosts, vectors and pathogens.

In effect, wetlands are 'meeting places' where humans, domestic animals and wildlife are increasingly coming into contact, creating interfaces, which together with other threats are resulting in disease emergence or re-emergence affecting public health, livestock productivity, ecosystem health, biodiversity and economies at multiple scales.

Figure 1-2. Wetlands are at specific risk of emerging and re-emerging diseases due to a range of factors including their association with people (as shown in this housing development), livestock and industry (*WWT*).

The dynamics of diseases in wetland ecosystems are changing rapidly; the most important driver is unequivocally the dramatic growth of the human population and the rapid ecological change driven, directly or indirectly, by human activity. In numerous areas of the world, infectious diseases of domestic animals that were previously endemically stable (vector, host and environment co-existing with the virtual absence of clinical disease) are now unstable due to anthropogenic changes (*e.g.* as seen with the diseases theileriosis and heartwater).

Table 1-2 provides some of the diseases that result from the specific attributes of wetlands and specific forms of rapid social and ecological change.

Table 1-2. Selected factors driving disease emergence in wetland systems (adapted from Morse, 2004).

Factor	Examples of specific factor	Examples of diseases in wetlands
Agriculture	▪ Production systems ▪ Dams ▪ Water management changes ▪ Habitat loss/degradation ▪ Pollution	▪ Highly pathogenic avian influenza, *e.g.* H5N1 ▪ Schistosomaiasis ▪ Avian botulism ▪ Harmful algal blooms ▪ Lesser flamingo *Phoeniconaias minor* toxicoses ▪ Salmon and trout sea lice
Globalisation	▪ Food production changes ▪ International trade ▪ Alien species	▪ Highly pathogenic avian influenza ▪ Amphibian chytridiomycosis ▪ Crayfish plague
Human demographics and/or behaviour	▪ Poor sanitation ▪ Wildlife interface ▪ Encroaching wildlife areas ▪ Civil conflict ▪ Non-sustainable harvesting ▪ Hunting	▪ Cholera and other intestinal parasites (micro and macro) ▪ Ross River fever ▪ Acanthocephalan outbreaks in eider ducks *Somateria mollissima* ▪ Lead poisoning
Technology and industrial changes	▪ Food production changes ▪ Breakdown in medical services	▪ Antibiotic-resistant pathogens ▪ Cholera and typhoid
Climate change	▪ Changes in rainfall and temperature	▪ Avian botulism ▪ Bluetongue disease ▪ Yellow fever

These ecological, environmental and demographic factors affect disease dynamics in three main ways:

- **Increased disease transmission risk**
  A growing human population has increased interspecies contact *i.e.* interface between wildlife, humans and domestic animals, consequently increasing the risk of disease transmission between these sectors.

Figure 1-3. Livestock market in Mali, sourced from OIE Media centre (©N.Denormandie/OIE).

- **Increased movement of pathogens**
  Globalisation (of travel and commerce) and climatic change are increasing the movement of pathogens, food, livestock, wildlife and humans worldwide. Animal translocations (of livestock and wildlife) have increased substantially in recent decades and have often resulted in serious disease outbreaks. Such movements drive disease emergence directly through the following mechanisms:
  - Infection is spread to a new area by the movement of infected animals or fomites;
  - Disease vectors are spread to a new area *e.g.* due to climate or *via* human transportation; and/or
  - Host animals are moved to a new area (exposure of immunologically naïve animals to new pathogens).

  The introduction of invasive alien species can also directly spread pathogens and indirectly drive disease emergence (*via* increased competition for resources with an invasive species increasing stress and energy expenditure rendering an animal more susceptible to disease).
  ►**Section 2.5. Control of infectious diseases and invasive alien species**

- **Increased susceptibility of an animal to disease**
  Stressors usually cause or result in an energetic cost and/or change in normal biological function to an animal and can increase susceptibility to disease. Populations under stress are more susceptible to disease outbreaks and length of exposure to a stressor determines how likely it is that disease will develop. Most ecological systems are exposed to multiple stressors simultaneously (or in series); subclinical stressors (*e.g.* hypoxia, pollutants) can make organisms vulnerable to other secondary stressors (*e.g.* malnutrition, disturbance) and disease progression.

  Activities that can increase stress and thus increase disease susceptibility, include the transportation and/or translocation of animals, isolation, restraint and overstocking (factors particularly relevant to the spread of disease of livestock). Other stressors are as diverse as hunting, increased genetic homogeneity and long-term toxin exposure.

  Rapid environmental changes caused by human activity have amplified the role of disease as regulation factors in species survival. These environmental stressors include the destruction or conversion of wildlife habitat by humans, resulting in habitat loss, degradation, fragmentation and macro- and microclimate changes.

Fragmentation of habitat by human encroachment can result in vulnerable isolated wildlife populations in human-made 'island ecosystems' which are at increased risk of diseases and their impacts.

Environmental pollution can also be a direct cause of non-infectious disease (*e.g.* lead poisoning or oestrogenic agents disrupting hormone function) and may also drive disease emergence. Air, water, light, noise and thermal pollution must also be considered as stressors or drivers of disease in wetland systems.

Nutritional stress (lack of, poor, or imbalanced nutrition) can lead to immunological impairment and often tip the balance between health and disease in animals (e.*g.* nutritional stress has been linked with increased prevalence of Hendra virus in fruit bats in Australasia.

*These stressors and drivers of disease **should not be considered in isolation** as several factors often contribute (synergistically) to the emergence of a wetland disease.*

FURTHER INFO 1-1. The impact of climate change on animal disease

Climate change is having an unprecedented worldwide impact on the emergence and re-emergence of animal diseases, including zoonoses. The recent rise in emerging infectious diseases has included considerable increases in the number of vector borne-emerging infectious diseases during the 1990s. Climate change is thought to play a significant role in this with compelling evidence of variations in climate impacting diseases such as malaria, dengue fever and plague in humans, bluetongue in livestock and other diseases of amphibians and corals.

As the climate continues to change, the effect of pathogens on wildlife, livestock and humans is also likely to change. Although there is a consensus among scientists that climate change will result in general increases in disease incidence and distribution, it is worth noting that due to the complexities of climate change-disease interactions some diseases are likely to decrease in frequency or prevalence.

How might climate change bring about animal disease expansion or change?

- **Rising temperatures** may alter the population size and/or distribution of pathogens, vectors and hosts.
  Pathogens: pathogen growth can be temperature dependent.
  - Cholera is caused by *Vibrio cholerae*, a water-borne bacterial pathogen, whose prevalence is expected to rise with global temperatures, moderate increases in temperature and rainfall may precipitate outbreaks.
  - Anomalous high ocean temperatures have been linked to coral disease outbreaks.
  - Conversely, pathogens that prefer cooler temperatures, *e.g.* fungal entomopathogens of insects, may decline.

  Vectors: temperature increases may reduce restrictions on insect distribution. Mosquitoes can now be found at Everest base camp, traditionally a place where low temperatures and high altitude have deterred the insect; annual temperature increases of 0.9° C have caused this shift in distribution. Temperature changes may also affect vectors by altering biting rates or length of the transmission period.

  Hosts: host distributions have already altered due to climate change. In the Arctic, southern species, such as white-tailed deer *Odocoileus virginianus*, are invading areas normally occupied by caribou *Rangifer tarandus*. The deer can carry ticks and therefore have the potential to distribute tick-borne parasites such as those responsible for Lyme disease.
- **Increased precipitation** – heavy rainfall, especially following drought, can cause insect population

booms by increasing larval habitats; flooding events may increase water-borne diseases such as cholera or leptospirosis; storms can increase transport of waste water diseases to groundwater.

- **Variations in rainfall/dry season patterns** – the Ebola virus is linked to unusual rainfall patterns, as climate change disrupts seasonal rainfall, increased episodes may be expected. Rodent populations are known to increase following mild/wet winters in temperate regions, rodent-borne diseases include: Lyme disease, tick-borne encephalitis and hantavirus pulmonary syndrome.
- **Increased drought and heat** – drought can cause livestock and wildlife to congregate around limited water resources increasing risk of pathogen transmission (*e.g.* bovine tuberculosis may proliferate in such a manner). Grazers would also suffer with restricted food availability due to limited vegetation growth. Such stresses would predispose animals to greater parasite load and greater risk of diseases progressing from a sub-clinical to a clinical state [► example below].
- **Forcing animals to adjust movements or migration** – climate dependent resources (*e.g.* vegetation cover) may be altered which in turn may affect movement patterns increasing the potential for introductions to, or encounters with, novel pathogens.
- **Reducing the number of long-distance migrations** – changes to habitats and weather conditions may encourage animals to remain at one site instead of undertaking traditional migrations. In China rising temperatures causing increased glacial runoff into nearby wetlands has been cited as one reason why unusually large numbers of geese are remaining at Qinghai Lake over winter instead of migrating to India. With greater concentrations of birds comes greater concern about increased transmission of avian viruses such as highly pathogenic avian influenza H5N1.
- **Human actions** – climate change may result in shifts in distribution of fertile farmland to areas that encroach upon wildlife, increasing risk of transfer of infection between livestock, people and wildlife. Local land use changes are also expected to exert temperature and rainfall changes (*e.g.* reduced vegetation could reduce evapotranspiration and consequently, rainfall). Climate models predict that such changes will alter the distribution of malaria in Africa - in tropical Africa and in parts of the Sahel the spread of malaria will decrease and the risk of malaria epidemics will shift southwards.

Example: African lions, drought and disease

An example of how increasing extreme weather may cause the expansion of animal diseases occurred in 1994 and 2001 in Tanzania. During these years there was unusually high mortality of lions *Pathera leo* due to canine distemper, an endemic disease that is not usually fatal. *Post mortem* analyses had also revealed higher than usual levels of the tick-borne parasite *Babesia leo* and it was this co-infection that had reduced the lions' immunity and caused them to succumb to canine distemper. A link was drawn between the environmental conditions and the deaths: in 1994 and 2001 there had been extended droughts that had weakened the local herbivore population and allowed the ticks that parasitised the herbivores to prosper; the lions feeding on the weakened herbivores were then exposed to greater infection by *Babesia* causing susceptibility to canine distemper. With climate change expected to increase the number of drought events in Africa, lion populations are likely to continue to suffer large losses to an already threatened population.

1.4 Effects of disease on biodiversity

It is well recognised that diseases play an integral part of ecosystems and specifically an important role in population regulation through effects on both birth and death rates. Diseases can shape population age structures and geographical range, *e.g.* distribution of cervids in eastern and north eastern America is determined by a meningeal worm. Yet the emergence of numerous and novel diseases related to human activities can negatively impact biodiversity and contribute to species declines and even extinctions. The previously discussed drivers of disease affecting the wider environment, host populations, parasites and their vectors, together with factors specific to wildlife, such as, intensive conservation management of wildlife, effects of providing supplemental food including feeding stations, and translocations have all contributed to the negative consequences of disease at a population level.

Diseases can alter wildlife communities in the short and long term. For example, the introduction of myxomatosis to control rabbits contributed to the extinction of large blue butterflies *Maculinea arion* in the UK (through knock-on effects on vegetation, vertebrate and invertebrate populations and community structure). The introduction of rinderpest virus to Africa altered abundance and distribution of herbivore populations dramatically throughout the continent.

Figure 1-4. Diseases can alter wildlife communities in the short and long term, affecting age structure and geographical distribution of species such as these African wildebeest *Connochaetes taurinus* (*WWT*).

Communities can be impacted additionally when species, such as ‘keystone species’, are negatively affected by disease. Perhaps this is best illustrated by effects of diseases on corals, with dramatic changes throughout communities and ecosystems.

The effects of disease on isolated or threatened species can be particularly severe. Small populations lose heterozygosity and are thus inherently more genetically susceptible to disease (and immunologically naïve isolated populations, such as island species, tend to have relatively limited genetic diversity). Additionally, individuals and populations under stress (*e.g.* caused by habitat degradation) can lose immunocompetence. The overall effect can be to create populations at greater risk of disease where the impacts can be particularly serious, causing either extinction or further loss of heterozygosity, further disease susceptibility and possibly jeopardising the survival of the population.

Figure 1-5. Whooping crane *Grus americana,* a threatened species which has suffered from diseases whilst sympatric more abundant sandhill cranes *Grus canadensis* have been relatively unaffected (*Ramsar*).

To illustrate that disease has become a cross cutting conservation issue, we have used as a proxy, an analysis of multilateral environmental agreement instruments, specifically under the Convention on Migratory Species, of the number of instruments mentioning the terms ‘health’ or ‘disease’. As Figure 1-6 illustrates this has increased significantly over the last two decades. The issue of disease will no doubt continue to be highlighted on conservation agendas.

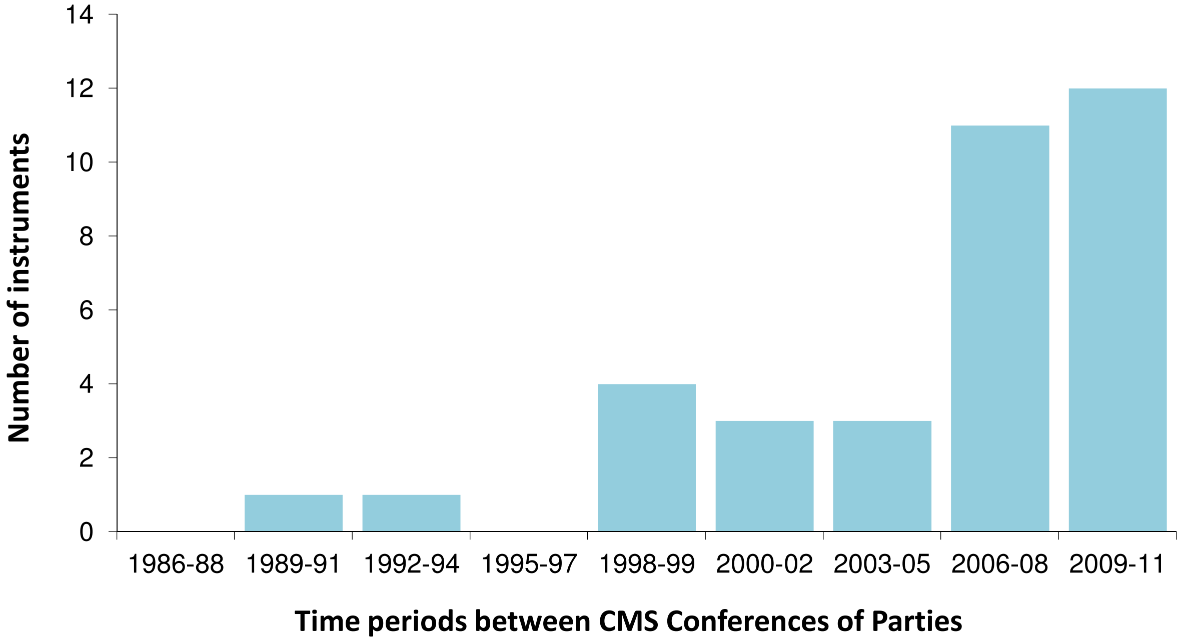

Figure 1-6. The increasing frequency of references to animal disease (or health) in formal documents of CMS (including COP Resolutions), its associated Agreements and other linked treaties for migratory species, from 1985 to 2012 (Lee, unpublished). Data are total numbers of formal documents containing the words "disease" and/or "health" by triennial periods.

As a final point to consider in this section on the effects of *disease* on *biodiversity*, it is probably worth reflecting on the effects of *biodiversity* on *disease*. Biodiversity in itself helps to provide resilience to ecosystems, buffering against disease emergence. This needs to be borne in mind when considering management of wetlands and any disease control activities negatively impacting biodiversity may have longer term poorer health outcomes.

Figure 1-7: Biodiversity in itself helps to provide resilience to ecosystems, buffering against disease emergence (*WWT*).

1.5 Effects of disease on livestock

Despite access to veterinary care and management, disease often has a far greater impact on livestock populations than wild populations, particularly in intensive systems, due to the nature of managing high densities of often genetically similar individuals in circumstances where hygiene standards may be suboptimal. Diseases in livestock create welfare issues and loss of productivity either by the fatal action of the disease itself or through an enforced cull of affected stock (*e.g.* as happens in control of highly pathogenic avian influenza). Table 1-3 summarises the impact of a number of wetland diseases on livestock.

Even when animals do not die, general unthriftiness can readily affect income, food security and human health. Such effects include reductions in reproduction and productivity (*e.g.* brucellosis or schistosomiasis), increased susceptibility to other diseases or predation, or a reduction in an animal's ability to respond to other environmental stresses (*e.g.* as is the case in African animal trypanosomiasis). Environmental stressors might be the catalyst for a disease to progress from a sub-clinical to a clinical state (*e.g.* salmonellosis). Some infections may cause infertility or spontaneous abortions (*e.g.* brucellosis and leptospirosis) whereas others may affect production by specifically affecting the young, pregnant or lactating females (*e.g.* salmonellosis or leptospirosis).

These factors together with potential impacts on trade of livestock can result in significant impacts on livelihoods. The importance of healthy livestock is illustrated in the key support of northern

African farmers in their helping to eradicate rinderpest from their cattle. They actively engaged in vaccination and other disease control measures for their cattle recognising that childhood disease vaccination programmes were of negligible value if their cattle died, as without protein security the survival of the children was in doubt.
►**Case Study 2-1. Rinderpest – eradication of a disease affecting all sectors.**

Perhaps the most important issue affecting wildlife and livestock health is the ever increasing interface between these sectors. Feeding a burgeoning human population pushes our livestock production into wild places and wildlife moves into human habitation to exploit new habitats and resources. Most (77%) infectious diseases of domestic animals are common to wildlife, so the control of a disease in domestic animals can be impeded by its presence in wildlife. Whilst culling or other disease control measures in infected livestock can reduce levels of disease, if the disease persists in a wildlife reservoir it can spillback to domestic animals at a later point. Local and global movement of domestic animals for trade and farming can help to spread disease and also introduce novel parasites to naïve livestock populations.

Production systems are also generators of new diseases, driving the emergence of novel pathogens with potential for affecting livestock, wildlife and human health. Highly pathogenic avian influenza H5N1 illustrates this very well. The use of scrapie-affected sheep as a protein source for cattle fodder provided a route for the emergence of bovine spongiform encephalopathy in the UK in the 1980s. Given the need to feed humans into the future it seems certain that livestock production systems will ensure that there are many challenges ahead for pathologists, other diagnosticians, animal and human health services and society as a whole.

Figure 1-8. Domestic ducks feeding in That Luang marsh in Laos. Wetlands provide an interface for domestic animals and wildlife as well as people allowing transmission of pathogens between these sectors (*Sally MacKenzie*).

Table 1-3. Selected wetland diseases affecting livestock.

Disease	Hosts*	Impact on livestock
Schistosomiasis	Cattle, sheep, goats. Wild mammals and wildfowl are also affected.	An estimated 165 million animals are infected in Africa and Asia, most infections are sub-clinical but the disease can still cause serious morbidity and mortality. Farmers suffer significant reductions in productivity due to disease burden. Susceptibilty to other environmental stressors is also increased.
Peste des petits ruminants (PPR)	Small ruminants - predominantly sheep and goats	PPR causes heavy losses to goat and sheep stock and thus has knock-on effects for livelihoods and food security.
Leptospirosis	Cattle, sheep, goats, pigs.	Mortality can be high in calves and young or weak piglets. Adult mortality is low and many animals exhibit mild to no clinical signs. Some infections may cause infertility and spontaneous abortion in cattle.
Brucellosis	Cattle, swine, goats, sheep, other ruminants.	High mortality of unborn animals, the disease can be debilitating and causes loss of productivity and welfare problems. Trade restrictions increase economic losses.
Duck virus enteritis	Ducks and geese	In susceptible domestic waterfowl flocks, high percentage mortality and reduced egg production can occur.
Epizootic ulcerative syndrome	Wide range of wild and farmed fish	High losses to fish farmers through mortalities, reduced productivity and market rejection due to presence of lesions affecting consumer confidence.
Lead poisoning	Mammals, poultry including waterfowl.	Lead is a common cause of morbidity and mortality in livestock, particularly for sheep and cattle. Large scale stock losses can occur if they are not removed from the source of exposure promptly.
Salmonellosis	Most commonly in poultry and pigs	Many infected animals will not show clinical disease. In mammals, clinical disease is most common in very young, pregnant or lactating animals, and often occurs after a stressful event. Outbreaks in young ruminants, pigs and poultry can result in a high morbidity rate.
African animal trypanosomiasis	Cattle, swine, camels, goats and sheep.	Trypanosomiasis threatens 50 million cattle in Africa and can reduce livestock holdings by 10-50%. The disease has a high morbidity rate and is often chronic in susceptible animals. The mortality rate can reach 50-100% within months of exposure, particularly if the animal is exposed to poor nutrition and other stresses.
Bovine tuberculosis	Cattle plus a wide range of wild and domestic mammals.	Significant importance to the cattle industry through loss of production, control measures and trade restrictions. Presence of the disease may also lead to loss of consumer confidence in milk and beef products.

** Not all hosts are listed.*

1.6 Effects of animal disease on humans

There are over 200 described zoonotic diseases and their effects, which may depend on both the pathogen and the host, are varied ranging from mild headaches to death. The majority (60%) of emerging infectious diseases in humans are caused by zoonotic pathogens. Livestock production systems provide opportunities for zoonotic disease transmission and increased human population density living with domestic livestock and pet animals is linked to a rise in the number of zoonotic infections in humans. Additionally, wildlife plays a key role by providing a 'zoonotic pool' from which new diseases may emerge. Of the 60% of emerging infectious zoonoses, 72% have a wildlife origin. Human encroachment into wildlife habitats and wildlife utilising urban settings, as well as trade and use of wildlife (*e.g.* bushmeat), increases disease transmission risks.

As well as the direct impact of animal diseases on humans, there are numerous indirect impacts mainly caused by the reduced production of livestock in terms of both food security and quality and reduced income linked to production losses and trade restrictions.

►Section 1.5. Effects of disease on livestock.
►Section 1.7. Economic impacts of animal diseases.

Figure 1-10. An increasing range of interfaces between humans and animals allows zoonotic diseases to emerge.

1.7 Economic impacts of animal diseases

The economic consequences of animal disease are numerous, varied and occur at multiple scales from local to international. There are economic losses to livestock production as disease causes direct mortality and morbidity and reduces production efficiency, *e.g.* feed conversion efficiency and/or egg/milk yields can suffer. Production efficiency is also affected if a disease forces farmers to use resources sub-optimally, *e.g.* using cattle resistant to trypanosomiasis is one option for farmers affected by the disease, however this involves a trade-off because these cattle are smaller in size and less productive (accepting that in a trypanosomiasis region it is more productive to use the trypanotolerant breeds of livestock rather than suffer losses of 'more productive' yet less resistant breeds).

Disease also causes losses of revenue from restrictions on animal movement and trade, costs of control measures (including veterinary treatments) which can be prohibitive, negative impacts on agriculture and aquaculture markets, socio-economic influence on livelihoods, public health concerns especially in the instance of zoonotic disease, and even loss of income to tourism initiatives, *e.g.* where disease reduces wildlife population numbers and therefore the likelihood of providing a tourist attraction.

For both domestic animals and wildlife, there are costs associated with disease prevention: monitoring, surveillance, preventative treatments, vaccines and vaccination programmes can all be expensive. However, the costs of disease control operations following an outbreak can be even more so: as a general principle, prevention costs provide a sound investment.

Although complicated, the economics of disease management need to be seen in the broader context of ecosystem health [►**Section 2.3. The ecosystem approach to health in wetlands**]. Viewing disease management from this perspective which includes 'all' the costs of loss of ecosystem function and benefits can help determine appropriate disease control strategies. Although disease may affect income in one sector there may be other compensations. As an example, losses and theoretical losses to livestock production in endemic African animal trypanosome areas allow areas to be left for wildlife from which other direct revenue can flow, *e.g.* through tourism initiatives.
►**Section 4.3.1. African animal trypanosomiasis.**

A cost-benefit analysis, or decision tree, for example, may be useful when comparing the relative merits of different strategies.

Table 1-4. Examples of the economic impacts of animal diseases.

Disease	Economic impact
Peste des petits ruminants (PPR)	PPR in Africa, the Middle and Near East, South West and Central Asia threatens a billion strong population of ruminants and affects economies based on losses of meat, milk, offspring and mortalities and morbidity, as well as disease control. Annual PPR losses in India alone are estimated at 1,800 million Indian rupees (US$39.4 million).
Highly pathogenic avian influenza (HPAI) H5N1	The outbreak of HPAI (HPAI) in Hong Kong in 1997 is estimated to have cost US$100s of millions and global estimates from outbreaks since 2003 run at billions of dollars.
Classical swine fever	The continued presence of classical swine fever in Haiti has been estimated to result in an annual reduction in income of US$2.7 million for the local small holder producers.
Rabies	It is estimated that the US spends a minimum of $230 million a year to control this disease.
Foot and mouth disease	The 2001 foot and mouth disease outbreak is estimated to have cost the UK £1.2 billion.

1.8 The scope, aim and objectives of this Manual

This Manual has been prepared at the request of the Conference of Parties of the Ramsar Convention (Resolution X.21) and is targeted principally at wetland managers, but also contains much information of relevance to others involved with wetland conservation either at the scale of individual wetlands or more widely.

Covering the entire range of diseases affecting wetlands is beyond the scope of this Manual. Instead, this Manual focuses on diseases primarily affecting animals[1] (with specific information for a subset of these diseases). Diseases of organisms other than animals, such as plant diseases and diseases primarily of humans, such as malaria and dengue fever, are not included. We hope, however, that additional volumes can be produced to cover these topics.

The Manual is intended for use at wetlands anywhere in the world. The practicalities and resources available may vary but the principles of disease management remain the same.

Written for wetland managers, this Manual aims to bring together what is currently known about animal diseases affecting wetlands and what options are available for managing them. Following an introduction to the issue of diseases in wetlands, we present the general principles of disease and its management in wetlands. We then provide descriptions of a selection of management practices for preventing and controlling disease outbreaks. Thereafter, factsheets present descriptions of a selection of priority diseases[2] affecting wetlands and information to assist in their management. We end with suggestions for where to obtain further information and direction.

Included in the appendices are categories of additional information which we hope will be useful, including a glossary of commonly used terms relating to disease, a list of countries which are members of the World Organisation for Animal Health (OIE) [►**Appendix IV**], a list of diseases notifiable to the OIE [►**Appendix V**], a summary of the priority disease factsheets, and a summary of the most important disease issues relevant to policy makers. Throughout the Manual key messages for wetland managers and policy makers are highlighted.

As seen in Table 1-2, the drivers for disease emergence in wetlands are closely associated with human activity and disease prevention in these habitats lies primarily with land users and managers, together with decision makers. Use of this Manual should provide managers with enhanced understanding that will help assist better informed decision making with respect to preventing and controlling disease in wetlands. This will assist with the task of maintaining the ecological character of wetlands – an essential element of Ramsar's wise use agenda. It should also materially benefit human communities dependent on wetlands by reducing disease risk either directly, or indirectly, to their livelihoods by impacts on livestock and other agricultural interests.

[1] In this Manual 'animals' refers to non-human animals.

[2] As determined at one of expert workshops *i.e.* diseases with greatest impact on human and animal health and livelihoods in wetlands ►**Appendix VI**

Figure 1-11. The drivers for disease emergence in wetlands are closely associated with human activity and thus disease prevention in these habitats lies primarily with wetland managers and users. This Manual aims to inform these key personnel (*WWT*).

In summary…

Aim of this Manual:

Well-informed decisions by wetland managers and policy makers with regard to the prevention and control of animal diseases in wetlands so as to ensure wise use.

Objectives of this Manual:

- To explain the **principles** of disease prevention and control;
- To provide guidance on **practical measures** for disease control in wetlands;
- To provide generic information on a selection of **priority diseases**;
- To provide advice on incorporating disease control measures into **site management plans**; and
- To provide links to **further resources and information**.

KEY MESSAGES FOR WETLAND MANAGERS AND POLICY MAKERS

- The term '**disease**' is used to define any impairment to health resulting in dysfunction. There are **many disease types**, including: infectious, toxic, nutritional, traumatic, immunological, developmental, congenital/genetic and cancers.
- **Disease is often viewed as a matter of survival or death when, in fact, effects are often far more subtle**, instead affecting productivity, development, behaviour, ability to compete for resources or evade predation, or susceptibility to other diseases factors which can consequentially influence population status.

- **Well functioning wetlands** with well managed livestock, with little interface, with well managed wildlife should provide human wetland dwellers with the **ideal healthy environment in which to thrive.**
- **Disease is an integral part of ecosystems** serving an important role in population dynamics. **However, there are anthropogenic threats affecting wetlands** including climate change, substantial habitat modification, pollution, invasive alien species, pathogen pollution, wildlife and domestic animal trade, agricultural intensification and expansion, increasing industrial and human population pressures including the interface between humans and domestic and wild animals within wetlands, all of which may act as drivers for emergence or re-emergence of diseases.
- **Wetlands are meeting places** for people, livestock and wildlife and **infectious diseases can be readily transmitted** at these interfaces.
- **Stress is often an integral aspect of disease** capable of exacerbating existing disease conditions and increasing susceptibility to infection. **There are a broad range of stressors** including toxins, nutritional stress, disturbance from humans and/or predators, competition, con-current disease, weather and other environmental perturbations. Stressors can be additive, working together to alter the disease dynamics within an individual host or a population.
- **Impacts** of disease on public and livestock health, biodiversity, livelihoods and economies **can be significant**.
- **The emergence and re-emergence of diseases has become a wildlife conservation issue** both in terms of the impact of the diseases themselves and of the actions taken to control them. Some diseases may be significant sources of morbidity and mortality of wetland species and in some cases (*e.g.* amphibian chytridiomycosis) can play a role in multiple extinctions of wetland species.

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