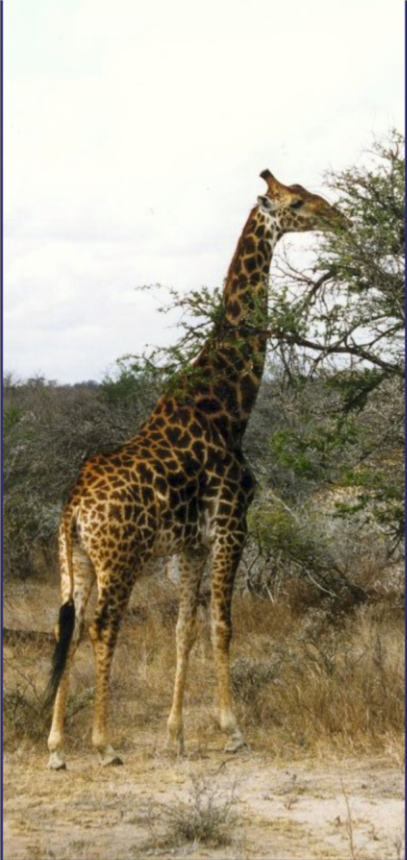


TRAINING MANUAL ON WILDLIFE DISEASES AND SURVEILLANCE



First Cycle

Workshop for OIE National Focal Points for Wildlife



Oie

TRAINING MANUAL ON WILDLIFE DISEASES AND SURVEILLANCE

**Workshop for OIE National
Focal Points for Wildlife**

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FOREWORD

Dr Bernard Vallat
Director General
OIE

Since the 1980s, the World Organisation for Animal Health (OIE) has formally recognised the need to expand its activities to the field of wildlife diseases and has established a permanent Working Group on Wildlife Diseases¹.

The OIE, within its role as the global reference organisation for animal health and welfare and its mandate to ensure transparency in the animal health situation worldwide, has constantly encouraged its Members² to improve the understanding of the disease situation in wildlife and to regularly report relevant information to the OIE.

At the 76th General Session of the World Assembly of OIE National Delegates in May 2008, the Delegates were requested to nominate national focal points for wildlife.

In 2009, detailed Terms of Reference for wildlife focal points were developed and the OIE launched a global programme of capacity building by organising training workshops region by region.

These workshops provide the National Focal Points with information on the role and responsibilities of Veterinary Services concerning wildlife diseases, including notification obligations and participation in the preparation and adoption of global OIE standards and guidelines.

They also update the participants on the role and activities of the OIE with regard to wildlife, the global animal health information system (WAHIS) and the improvements in wildlife reporting, and provide information on their role in supporting the OIE Delegate and opportunities to build regional and global networks.

¹ In 2010, the Working Group on Wildlife Diseases is composed of the seven following members: Dr William B. Karesh (President); Prof. Marc Artois (France); Dr Roy Bengis (South Africa); Dr John Fischer (USA); Dr T.A. Leighton (Canada); Dr Torsten Mörner (Sweden); Dr Yasuhiro Yoshikawa (Japan). Three Observers participate at the Working Group on Wildlife Diseases: Dr Kris de Clercq (represents the Scientific Commission); Dr Scott Newman (FAO); Dr Pierre Formenty (WHO).

² In 2010, the OIE has 177 Members (<http://www.oie.int/en/about-us/our-members/member-countries/>).

This Training Manual on Wildlife Diseases and Surveillance was prepared by Dr F.A. Leighton from the OIE Collaborating Centre for Wildlife Disease Surveillance and Monitoring, Epidemiology and Management, under the auspices of the OIE Working Group on Wildlife Diseases. It can be used in training workshops, with a view to providing practical advice on wildlife diseases and surveillance and facilitating an interactive working session for participants. This guidance will enable OIE focal points to better complete their national and international tasks and support OIE Delegates to more efficiently manage his/her Member rights and obligations.

I would like to thank Dr F.A. Leighton who generously contributed his time and extensive experience and the Members of the Working Group on Wildlife Diseases for the preparation of this excellent Training Manual.

INTRODUCTION

The OIE launched a global programme of capacity building for OIE Delegates and OIE Focal Points on different topics in 2009. The aim of this programme and the related regional training workshops is to explain and clarify the roles and responsibilities of the Focal Points nominated by the OIE Delegates and to facilitate consistency and harmonisation amongst OIE Members when assigning responsibilities to these officials (please refer to Appendix 1).

This training manual contains the core curriculum for the part of a workshop intended to inform and assist National Focal Points for Wildlife of the World Organisation for Animal Health (OIE)³ to gather and report information regarding the occurrence of wild animal pathogens and diseases in each of the OIE Members. It was prepared by F.A. Leighton of the OIE Collaborating Centre for Wildlife Disease Surveillance and Monitoring, Epidemiology and Management (Canadian Cooperative Wildlife Health Centre⁴) under the auspices of the OIE Working Group on Wildlife Disease⁵.

This Manual covers the wildlife topics associated with the workshop and contains the core content of presentations lasting about five hours. The presentations are followed by a two-hour session during which participants work in small groups to consider the elements of wildlife disease surveillance programmes and design such programmes for their own countries. The instructions for this small group exercise in surveillance programme design are included in Appendix 2 of this Manual.

³ World Organisation for Animal Health (OIE): <http://www.oie.int/en/>

⁴ For more information about the CCWHC, visit: www.ccwhc.ca

⁵ OIE Working Group on Wildlife Diseases: <http://www.oie.int/en/international-standard-setting/specialists-commissions-groups/working-groups-reports/working-group-on-wildlife-diseases/>

I. Definition of 'wildlife'

The term 'wildlife' means different things to different people in different contexts. Broadly speaking, it can apply to all wild plants and animals. However, the OIE is concerned only with animals, and wildlife focal points currently are asked to concern themselves with pathogens and diseases in 'terrestrial animals', which the OIE defines as 'a mammal, bird or bee.' For practical purposes, then, wildlife focal points are concerned with pathogens and diseases in mammals and birds which meet some definition of 'wildlife.'

In 1999, the OIE Working Group on Wildlife Diseases proposed the following way of defining different categories of animals that may require distinction:

“Wildlife” Defined¹

		Phenotype Selected by Humans	
		YES	NO
Animals live under Human Supervision and Control	YES	Domestic Animal	Captive Wildlife
	NO	Feral Animal	Wildlife

- Pathogens and diseases from all four groups must be reported
- Wildlife Focal Points may be asked to report on Pathogens in:
 - Wildlife
 - Feral Animals
 - Captive Wildlife (Zoos, Wildlife Parks, etc.)

¹ OIE Working Group on Wildlife Diseases 1999

In some countries, Wildlife Focal Points may be asked to gather information on pathogens and diseases in feral animals and captive wild animals as well as in true 'wildlife' as defined above. An example of feral animals would be wild pig (*Sus scrofa*) populations derived from domesticated pigs that now live without any reliance or control by humans. Examples of captive wildlife would be zoo animals and animals in some fenced private or public game parks.

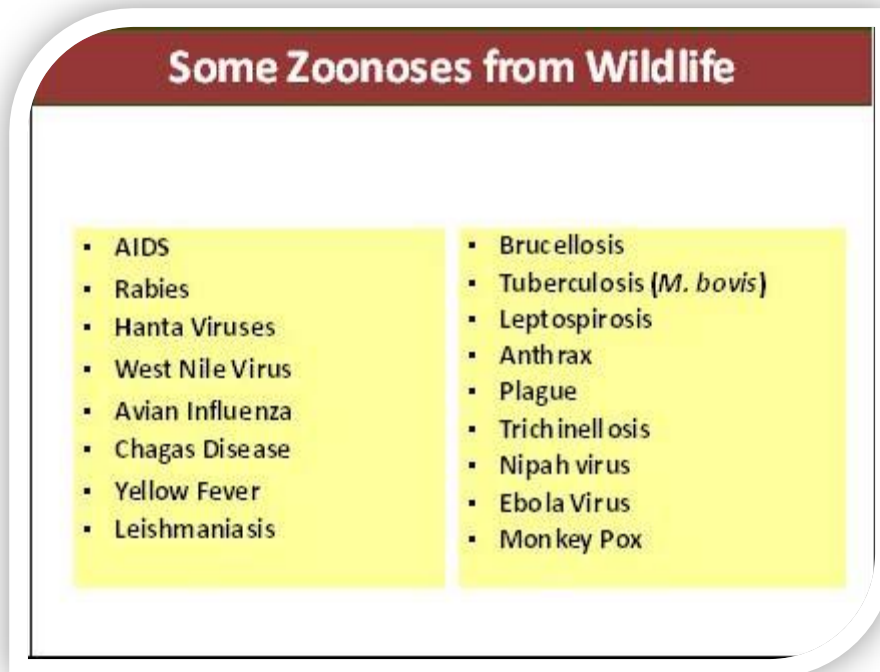
II. The socio-economic importance of wildlife pathogens and diseases

Pathogens present in free-living wild animals, and the diseases they cause, may be important for several different reasons:

1. Pathogens in wild animals may affect human health

Wild animals can be direct sources of infection for people with pathogens that can cause disease in humans (zoonotic pathogens). There are many human pathogens in wild animals. According to a recent study of human diseases, there are at least 144 human diseases derived from pathogens in wild animals that became important to human health in the past 60 years. Other zoonotic pathogens in wildlife have been important to human health for much longer than that.

Here is a list of some wildlife zoonotic pathogens and diseases:



Wild animals can be direct or indirect sources of all of these human diseases. For example:

- AIDS is caused by two human immunodeficiency viruses, each derived from an immunodeficiency virus normally found in wild African primates: HIV-1 from the Chimpanzee and HIV-2 from the Sooty Mangabeee monkey. Each of these viruses of wild primates has adapted to people through minor genetic changes, and now these viruses have become human pathogens that are transmitted from person to person independent of their original wild animal source.

- Yellow fever virus is maintained in wild monkey populations in much of South America and Africa. Mosquitoes transmit the virus among monkeys, from monkeys to people, and from person to person. The WHO estimates that 200,000 people develop yellow fever each year, of which 30,000 die.

- Chagas disease is caused by a protozoan parasite, *Trypanosoma cruzi*, which infects a wide range of wild and domestic mammals as well as people. It is transmitted from wild mammals to domestic mammals and to people by blood-feeding insects of the subfamily Triatominae. From 8-11 million people in Latin America suffer from Chagas disease.

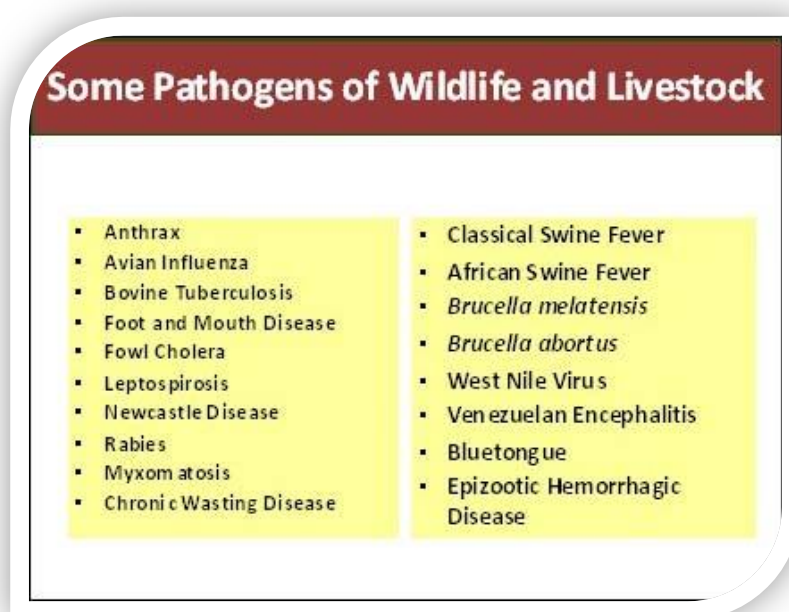
- Rabies virus is transmitted to people from infected wild and domestic animals directly through bite wounds. Over 55,000 people die of rabies each year, mostly in Africa (24,000) and Asia (31,000), and the principal source of infection is bites from domestic dogs. In 2003, wild animals, rather than domestic dogs, became the principal source of infection for people in South America. In many parts of the world, the reservoir for human infection with rabies virus appears to be a combination of populations of domestic dogs and wild carnivores. Some strains of rabies virus are maintained exclusively within populations of various species of bats, or of wild carnivores.

There are many more examples of zoonotic pathogens of wild animals, some of which are listed above. For all of these pathogens and for many others, wild animals can serve as the source of infection for people. So, pathogens carried by wild animals can be very important to human health and to public health and food safety programmes. Effective public health programmes require a complete understanding of the epidemiology of zoonotic pathogens in wild animals, as well as in humans and domestic animals.

Diseases that may affect people sometimes can be detected in wild animals before they pose a significant risk to human populations. This can be true with respect to diseases caused by poisons and environmental contaminants as well as for infectious diseases. For example, poisonous concentrations of mercury in fish have been detected by noting disease in fish-eating wild birds and mammals, and the occurrence of West Nile virus and plague in wildlife has been used as an index of risk to people of these infectious diseases.

2. Pathogens in wild animals may affect the health of domestic animals

Many pathogens can infect both domestic animals and wild animals. Some of them are listed on the table below. Programmes to control these pathogens in domestic animals can fail if the programmes do not take wildlife into account.

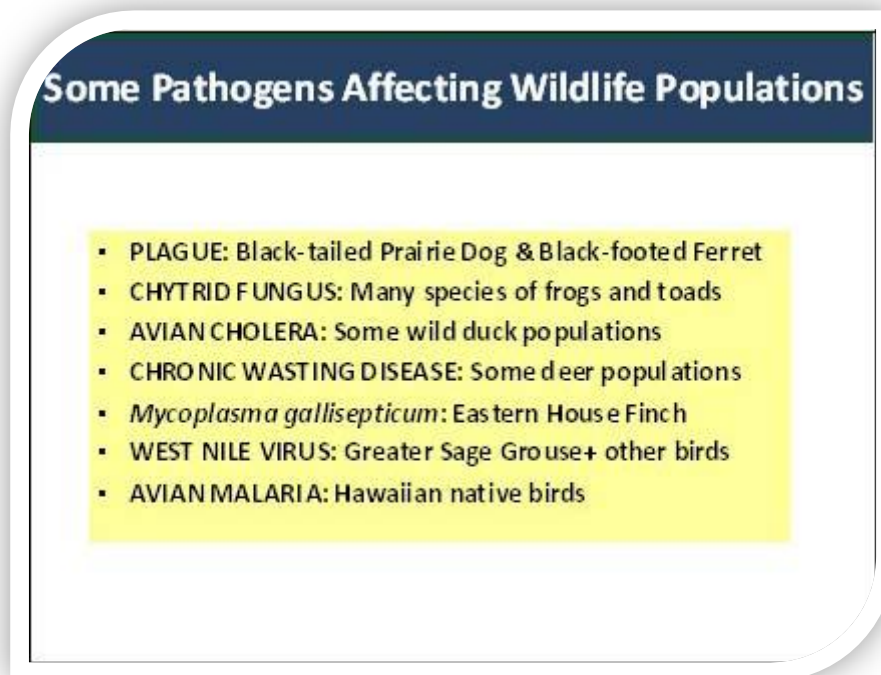


Some Pathogens of Wildlife and Livestock	
▪ Anthrax	▪ Classical Swine Fever
▪ Avian Influenza	▪ African Swine Fever
▪ Bovine Tuberculosis	▪ <i>Brucella melatensis</i>
▪ Foot and Mouth Disease	▪ <i>Brucella abortus</i>
▪ Fowl Cholera	▪ West Nile Virus
▪ Leptospirosis	▪ Venezuelan Encephalitis
▪ Newcastle Disease	▪ Bluetongue
▪ Rabies	▪ Epizootic Hemorrhagic Disease
▪ Myxomatosis	
▪ Chronic Wasting Disease	

Wild animals may be reservoirs for pathogens of domestic animals that affect international trade in animals and animal products. Some examples from this list would include bovine tuberculosis and foot and mouth disease. Pathogens from wild animals may cause severe disease in domestic animals, resulting in economic loss and threatening important food supplies. Examples from this list are Newcastle disease, and certain strains of avian influenza disease in wild animals also can serve as a warning of health risks to domestic animals that share the same environments. This often is the case for anthrax and West Nile virus.

3. Pathogens in wild animals may have important effects on wild animal populations

Pathogens and diseases can have a wide range of impacts on wild animals, ranging from subtle but important effects, such as reduced reproduction and life span or increased predation rates, to population declines from lethal disease. Some examples of lethal infections that can affect wild animal populations are in the table below.



Some Pathogens Affecting Wildlife Populations	
• PLAGUE:	Black-tailed Prairie Dog & Black-footed Ferret
• CHYTRID FUNGUS:	Many species of frogs and toads
• AVIAN CHOLERA:	Some wild duck populations
• CHRONIC WASTING DISEASE:	Some deer populations
• <i>Mycoplasma gallisepticum</i> :	Eastern House Finch
• WEST NILE VIRUS:	Greater Sage Grouse+ other birds
• AVIAN MALARIA:	Hawaiian native birds

Wild animals are of very high social and economic value to human societies. For that reason, diseases with significant impacts on wild animal populations pose important socioeconomic risks to society.

The Table below lists some of the ways wild animals are of value to people.



The relative importance of each of these values differs among societies, but all are true for all societies.

Economic Value can be very high, as high, or higher, than agriculture in some countries. Much of the world's human population depends, in part, on wild-captured terrestrial animals and fish for dietary protein. The value of wildlife to Recreation and Tourism also often is remarkably high. For example, in Canada, which is a major exporting country of agricultural products, the contribution of wildlife-dependent activities to the national Gross Domestic Product (GDP) was estimated to be \$12.1 billion in 1996. That same year, the total contribution to GDP from all of agriculture was \$12.3 billion. In the United States, a few years later, it was estimated that, on average, each American spent \$1,400 annually on wildlife-dependent activity, and that these activities made up 1% of the total national GDP of the country.

It is very likely that the actual economic value of wildlife to most countries is very high, and that activities that depend on wild animals contribute significantly to the national GDP.

There also are cultural and aesthetic values that various groups in society place on wildlife and which make wild animals valuable to those groups, and there is significant ecological value associated with wild animal populations. The many different populations of many different species of wild animals are required components of stable ecosystems. Thus, one major socioeconomic value of wildlife is its role as participants in ecosystem function and provision of ecosystem services such as clean air and water, fertile soil and ecological materials cycling (carbon, nitrogen, phosphorus, etc.).

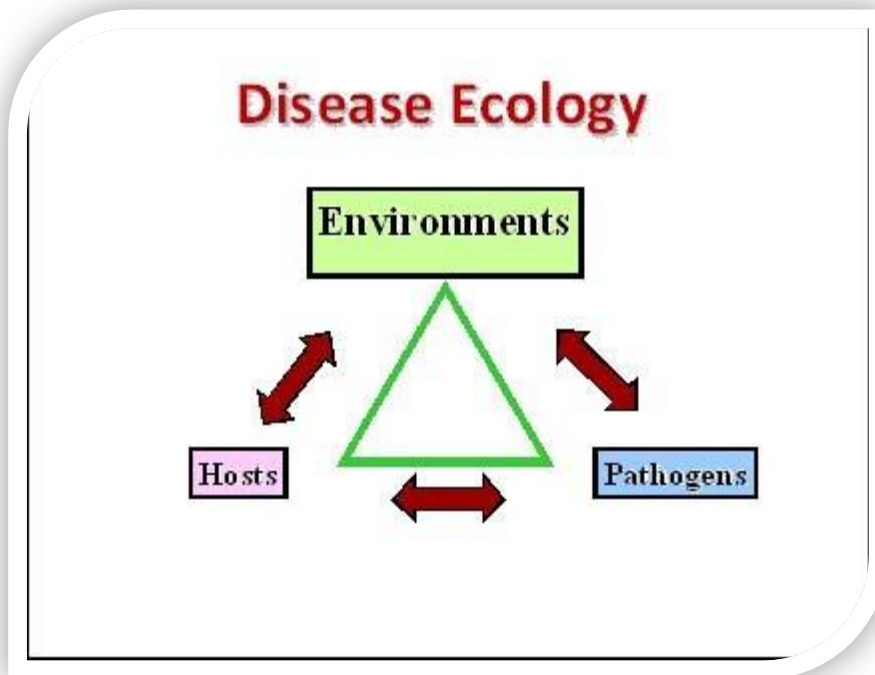
When diseases in wild animals occur in ways that have an important negative impact on wild animal populations, this can, in turn, have important and negative socioeconomic outcomes for people living in the affected areas.

III. The ecology of pathogens and diseases

1. Disease ecology: pathogens, hosts and environments

Ecology is the study of the interactions of organisms with each other and with their environments. Disease ecology is just a branch of ecology which studies the interactions among pathogens, the animals they infect, and their shared environment.

Whenever we attempt to manage human and animal diseases, to reduce their socioeconomic or their ecological impacts, we do so by trying to manipulate aspects of the ecology of those diseases. Thus, disease ecology is the branch of science that is most important to people responsible for disease management or control. The notion of disease ecology often is portrayed as a triangle of interactions.



This triangle depicts the three key factors that determine whether or not diseases will occur and what the various effects of a disease occurrence might be. When we consider the ecology of a disease, we consider all of the factors that cause an animal to become diseased or not.

These factors include such elements as the life cycle of the pathogen: how and where it lives, how it is transmitted among host species and under what circumstances, whether there are reservoirs of the pathogen in the environment, the susceptibility of individual host animals to the pathogen, the effect of the pathogen at various different levels of biological organization such as the individual animal, populations of one animal species, or communities of several different species or whole ecological systems.

These ecological factors are particularly important when considering pathogens in wild animals. The ecology of pathogens in wildlife often is more complicated than is the case for pathogens that affect only domestic animals or only people. Any programme to control a pathogen that infects wildlife must be designed with a full knowledge of the ecology of that pathogen and the circumstances under which it will cause disease.

2. Diseases have many causal factors

The triangle of relationships among pathogen, host and environment also provides a reliable framework for understanding how a disease is caused to occur. We often say that a particular disease is caused by a particular pathogen. Rabies is caused by rabies virus; plague is caused by *Yersinia pestis*. But this is not really true. Both rabies virus and *Yersinia pestis* must be transmitted to a person or a host animal in some way. Both must be maintained in some kind of animal reservoir from which transmission occurs. Many environmental factors will affect how easily each pathogen can be transmitted to a new host. The host may or may not become infected, depending on its immune status. If it becomes infected, it may become sick and even die, or it may become infected but experience no disease, no physiological dysfunction, as occurs in certain species resistant to plague. Thus, there are many factors other than the pathogen that help determine whether or not disease will occur in any particular circumstance. All of these factors are part of the 'cause' of a disease. These factors also influence whether an occurrence of a disease will affect few or many host animals, whether it will occur once or many times. Often, environmental factors, and changes in these environmental factors, have the most influence over whether or not disease will occur and on the size and importance of the occurrence.

3. Environmental factors and disease occurrence

a) Nipah virus in Malaysia, 1998

The outbreak of disease in people and domestic pigs due to infection with Nipah virus in Malaysia in 1998 is an example of the influence of environmental factors on disease occurrence. In that year, a previously unknown pathogen, now known as Nipah virus, caused disease in some large domestic pig herds. The virus was transmitted from pigs to people who were in contact with the pigs. This outbreak lasted only a few months, but resulted in infection of 265 people and death in 105 (39%), the destruction of about 1 million pigs to control the disease, and the loss of 36,000 jobs and US\$120 million in export sales. A search was made for the source of the new virus and it was soon discovered that fruit bats (*Pteropus* sp.) in the region were naturally infected with the virus. However, the virus was wide-spread in bat populations and clearly had been present in bats for a very long time. Why, then, did an outbreak of Nipah virus infection occur in pigs and people in 1998 and not before? Research to identify the cause or causes of this outbreak has identified several environmental changes that may have contributed to this outbreak. These include:

- 1) an exceptionally intense El Nino Southern Oscillation (ENSO) climate event which caused drought and extensive forest fires in the region, destroying fruit bat habitat,
- 2) prior decades of escalating forest cutting and conversion of forests to plantations, which also reduced fruit bat habitat,
- 3) recent establishment, for the first time in Malaysia, of large-scale intensive pig farms,
- 4) planting of fruit trees close to the large new pig farms.

The most thorough analysis of these factors has identified the establishment of large-scale pig farms and associated fruit orchards as the most important causal factors in the 1998 outbreak of Nipah virus infection in pigs and people. The fruit trees attracted bats to a close proximity with pigs, facilitating transfer of virus from bats to pigs. The large size of the pig farms provided a new, very large population of pigs through which the virus subsequently spread by pig-to-pig transmission. This resulted in many infected pigs and amplified risk of infection for people in contact with those infected pigs. The other environmental factors also may have

contributed to the outbreak but are much more difficult to quantify and relate directly to the outbreak.

b) Hantaviruses in the Americas

One environmental factor that can affect disease occurrence is biodiversity, the number of different species that live together in the same environment. In some environments, loss of biodiversity has increased the risk that people will become infected with pathogens from wild animals. One example is disease in people caused by several Hantaviruses and Arenaviruses in the Americas. In the Americas, there are a large number of such viruses in wild rodents which can cause severe disease in people.



Each of these zoonotic Hantaviruses and Arenaviruses typically is carried by one species of small rodent (see figure above). The viruses do not cause significant disease in the rodents, but they cause severe, often fatal, haemorrhagic fever or pneumonia in people. Research has shown that the incidence of these diseases in people is substantially higher in environments that have been severely disturbed, particularly by agriculture, compared to more complex, less disturbed environments. The main comparison has been between people living in complex natural environments and people living in similar environments that recently have been converted to crop production. Such environmental change results in a very simplified new environment with substantial loss of biodiversity and very few species of plants and animals remaining.

One might expect that the complex natural environment, with many more different species of animals and plants, would harbour a larger number of potential human pathogens and that people in these environments would be at greater risk of zoonotic diseases from wild animals. However, this has not proven to be the case. Instead, the opposite has been true. The people in the agricultural environment had a higher incidence of these diseases

Two mechanisms seem to account for this higher risk of disease in disturbed environments with greatly reduced biodiversity. One is that certain of the reservoir rodent

species are adaptable species able to thrive in the new environment while the majority of other rodent species do not adapt. There is, then, a large increase in the population of the reservoir rodent species in the disturbed environment with no competition from other similar species. The second is loss of the what some disease ecologists call the 'dilution effect'. In the complex natural environment, there are many different species of small rodents competing for food and living space. However, each of the zoonotic viruses generally infects only one of these species. When there are many different species in the environment, they cause the reservoir species to live at lower population density and transmission of virus among them is at a lower rate. Thus, the prevalence of infection in the reservoir species is low. In this sense, the other rodent species 'dilute' or reduce the concentration of the reservoir species and also reduce the prevalence of infection of the zoonotic Hantavirus and Arenaviruses within the reservoir species. People living in the complex natural environment thus are less likely to become infected because there are fewer infected rodents, even though there are many rodents. In the disturbed environment with very few species of small rodents, the dilution effect is removed and both the density of the population of reservoir rodents and the prevalence of infection within that reservoir rodent population increase. Thus, people living in this simplified, disturbed environment are at higher risk of acquiring infection from the wildlife reservoir.

IV. Emerging diseases and wildlife

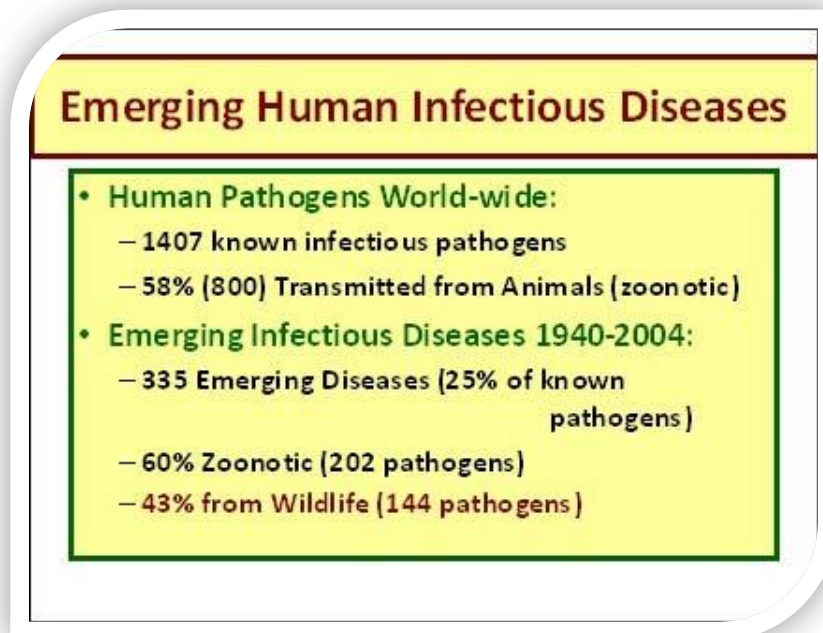
1. Emerging diseases

A major concern to human societies around the world is the recent increase in the number of important human and animal diseases, particularly infectious diseases. Previously unknown pathogens have caused previously un-recognised diseases, and the harm caused by some well-known pathogens has increased as well. These new or newly-important diseases have come to be called 'emerging diseases' or 'emerging and re-emerging diseases.'

An 'emerging disease' generally is defined as a disease due to:

- 1) a new pathogen resulting from the evolution or change of an existing pathogenic agent, or
- 2) a known pathogen spreading to a new geographic area or population, or increasing in prevalence, or
- 3) a previously unrecognised pathogen or disease diagnosed for the first time and which has a significant impact on animal or human health.

The term 'emerging disease' can be applied to diseases that affect people or to diseases that affect animals, and also plants. Many important emerging diseases are associated with pathogens which can infect many different host species and cause disease in wild animals, domestic animals and people.



(From: M.E.J. Woolhouse and S. Gowtage-Sequeria. *Emerging Infectious Diseases*, **11** (12), 1842-1847)

A recent study of human infectious diseases determined that there are approximately 1,407 human infectious pathogens world-wide. Of these, 800, or 58%, are zoonotic pathogens transmitted to people from animals. Another recent study identified 335 human infectious diseases that emerged in just the past six decades. This represents 25% of all known human infectious diseases. Of these 335 recently emerged human diseases, 202 (60%) are caused by zoonotic pathogens and 144 (43%) are caused by pathogens for which the main source is wild animals. The rate of disease emergence has increased during the previous six decades.

The majority of emerging human diseases in the past six decades have been zoonotic and the predominant source of these zoonotic pathogens has been wild animals. Thus wild animal pathogens have added major new burdens of disease to people and, although fewer data are available, wild animals also have been important sources of diseases affecting domestic animals.

2. Disease emergence

Because emerging diseases now are so significant to animal and human health, it is important to understand what drives the process of disease emergence.

'Humanity faces many challenges that require global solutions. One of these challenges is the spread of infectious diseases that emerge (or re-emerge) from the interfaces between animals and humans and the ecosystems in which they live. This is a result of several trends, including the exponential growth in human and livestock populations, rapid urbanisation, rapidly changing farming systems, closer integration between livestock and wildlife, forest encroachment, changes in ecosystems and globalisation of trade in animal and animal products.

The consequences of emerging infectious diseases (EID) can be catastrophic. For example, estimates show that H5N1 highly pathogenic avian influenza (HPAI) has already cost over US\$20 billion in economic losses. If it causes an influenza pandemic, it could cost the global economy around US\$2 trillion. Therefore, investments in preventive and control strategies are likely to be highly cost-effective.'⁶

There have been many studies of disease emergence in the past two decades. The findings of these studies are all very similar. The following list of risk factors for human and animal disease emergence is taken from several of these studies.

Risk Factors for Disease Emergence ("Drivers")

- **Increasing Host Populations: Human, Animal**
- **Changes in Land Use: Forestry, Agriculture**
- **Rural–Urban Human Migrations: Human Ecology**
- **Environmental Changes: Rapid, Large-scale**
- **Rapid Long-Distance Transport: Pathogens**
- **Trade in Wild Animals and Meat: Pathogens**
- **Pathogen Evolution: New Pathogens**

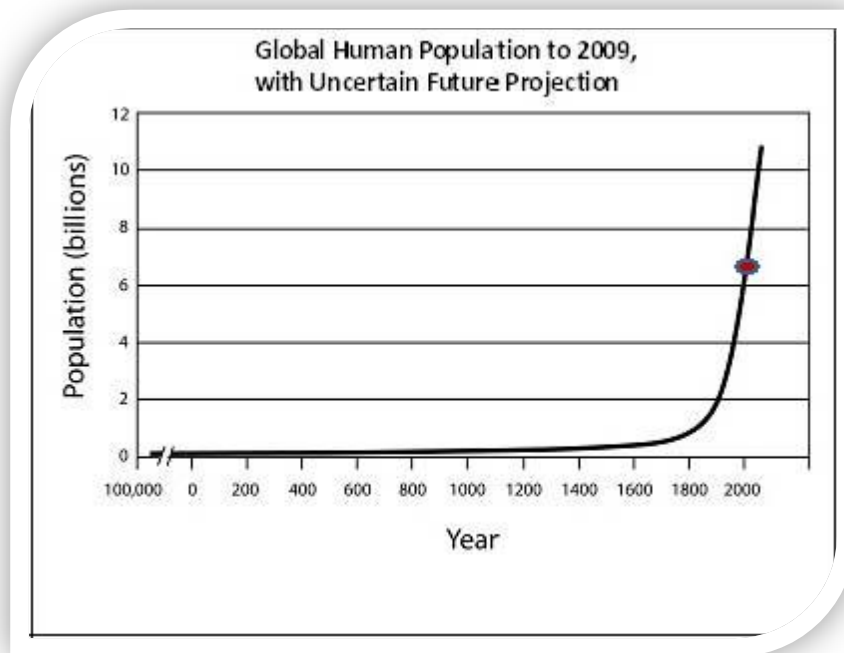
⁶ From: One World, One Health: A Strategic Framework for Reducing Risks of Infectious Diseases at the Animal–Human–Ecosystems Interface. A Consultation Document for the International Ministerial Conference on Avian and Pandemic Influenza. OIE, WHO, FAO, UNICEF, UNSIC, World Bank. Sharm el-Sheikh, Egypt, October 25, 2008

- Human and animal populations have increased exponentially since the industrial revolution of the mid-1800s. This sudden rise in numbers and densities of hosts for emerging pathogens is unprecedented in human history and is a major factor driving disease emergence. The graph below shows global human population growth from 100,000 years before present to 2009, with an uncertain projection into the future. Global livestock populations have shown a parallel increase in numbers in the past 150 years.

- There are many examples of large-scale environmental changes: large surface mines, the current rapid increase in atmospheric carbon dioxide, massive forest cutting, and expansion of agriculture.

- Rapid long-distance transport of people, animals, animal products, their pathogens and vector species such as mosquitoes also has increased in parallel with the rise of global human populations.

- Trade in wild animals and wild animal meat has risen extraordinarily fast in the past few decades. There are few studies of its magnitude, but legal trade is enormous and illegal trade may be as large again. In the Congo basin of Africa, it was estimated in 2002 that 4.9 million metric tons (tonnes) of meat from wild mammals was being harvested each year, and in the Serengeti National Park of Tanzania, it was estimated, also in 2002, that at least 52,000 people participated in illegal harvest of wild animal meat in this protected area.



- During this period of rapid population growth, human populations also have moved from rural to urban environments, resulting in major changes in human ecology.

Global Urbanization & Urbanization Growth Rates (from FAO 2006)		
Region	% Urban Population (2005)	Annual Urbanization Growth Rate 1991-2005
South Asia	29	2.8
East Asia/Pacific	57	2.4
Sub-Saharan Africa	37	4.4
West Asia & North Africa	59	2.8
Latin America/Caribbean	78	2.1
Developing Countries	57	3.1
Developed Countries	73	0.6
World	49	2.2

Of all of these influences and factors that contribute to disease emergence, the vast majority are environmental and ecological changes. And even the evolution of completely new pathogens is likely a response to changing environmental conditions resulting in new evolutionary selection pressures on pathogens and potential pathogens.

The studies of the driving forces behind disease emergence also help explain why disease emergence is occurring so rapidly now, at the beginning of the 21st Century, compared to earlier decades or centuries. These driving forces are, themselves, new. Human numbers, domestic animal numbers and environmental change is happening now at a rate and on a scale never before experienced by humankind.

3. Geography of disease emergence

Risk of disease emergence does not appear to be uniformly distributed around the globe. Instead, recent analysis suggests that it is concentrated in specific areas where the driving forces of, and risk factors for, disease emergence also are concentrated. In particular, the tropical zones of South and Central America, Sub-Saharan Africa and Southern Asia appear to be areas of high risk for disease emergence, and this is especially true for pathogens associated with wild animals.

4. One World, One Health

The growing scientific understanding of the driving forces of disease emergence has resulted in a new way of thinking about health management at all levels, from local to global. In this new view, it is recognised that there are many interconnections among the health of people, of domestic and wild animals and of the environment or ecosystem. It is not possible to manage disease and achieve health in any one of these sectors in isolation. Instead, disease management and health achievement must be approached by seeking relevant information and control points in all sectors, simultaneously. This will require a whole new level of interchange of information, coordination of policies and programmes, and collaborative management among authorities

responsible for domestic animal health, wildlife health, human health and environmental and ecological health.

This new paradigm for managing health and disease has come to be called the 'One World, One Health' approach, so named at a conference organized by the Wildlife Conservation Society in September 2004. It now is strongly supported by international bodies such as the OIE, the WHO, FAO and other United Nations organizations, and by the World Bank. It also is supported by many countries as a basis for national health management.

In the One World, One Health concept, disease prevention, surveillance, response and management are integrated across all relevant government units and social institutions. Such integration is entirely new to most governments and health management organisations, and successful implementation of the One World, One Health model will require creative new policies and a new high degree of day-to-day collaboration and communication among agencies which previously may have interacted very little.

Wildlife disease prevention, surveillance, response and management will be key components of health management in the One World, One Health model. This is one important reason that the OIE has placed a renewed emphasis on surveillance for, and reporting of, pathogens and important epidemiological events that occur in wild animals.

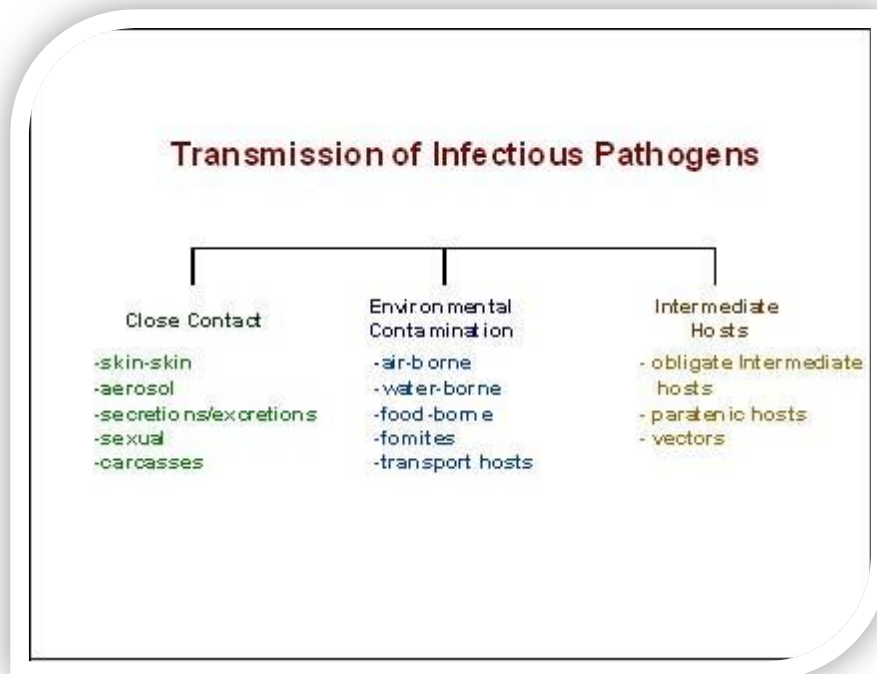
V. Pathogen transmission

Understanding how pathogens are transmitted among hosts often is essential to programmes that seek to control or reduce zoonotic diseases or diseases shared between wild and domestic animals.

Pathogen transmission can be very complicated. There are three broad, general routes by which pathogens can be transmitted among hosts

- close contact
- environmental contamination
- intermediate hosts.

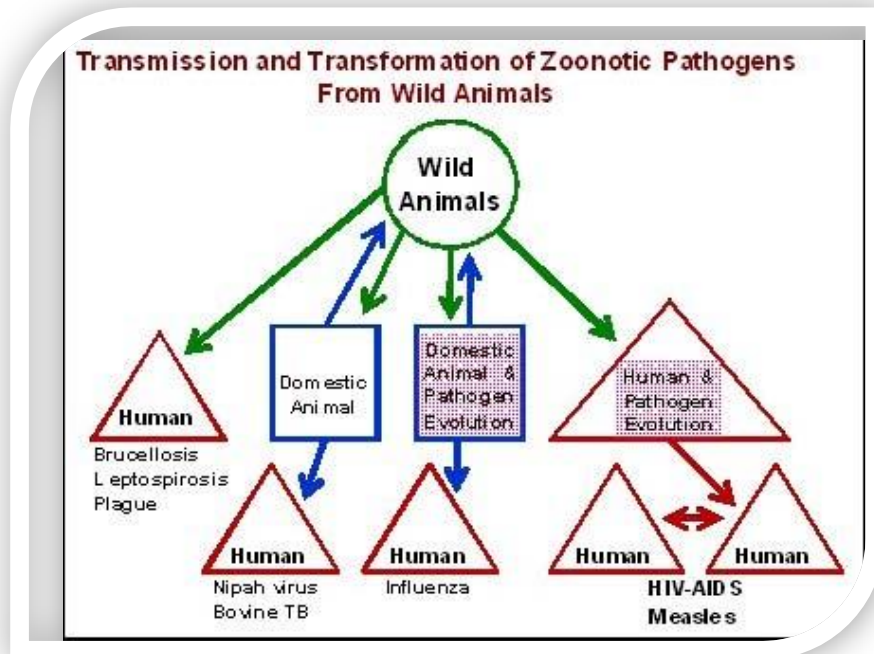
Each of these broad categories includes many different routes of transmission:



For example, transmission of dermatophyte fungi ('ringworm') or of mange mites (e.g. *Sarcoptes*) is commonly, perhaps exclusively, by skin-to-skin contact. On the other hand, bovine tuberculosis can be transmitted by several different routes, such as aerosols, excretion of inflammatory exudate, contact with carcasses of infected animals, or via fomites and food. Avian cholera and avian influenza often are transmitted through water. *Trichinella* and *Anasakis* nematodes are transmitted through food. Mosquitoes can serve as transport hosts for avian pox virus, and as true biological vectors for viruses such as yellow fever virus which undergoes development in the mosquito. The life cycle of many parasitic helminths include intermediate hosts and some include paratenic hosts which are not required in the life cycle but often are important in pathogen transmission.

To manage any infectious disease, it is essential to know very precisely how it is transmitted. These routes of transmission also are the mechanisms by which infectious pathogens maintain themselves and persist in animal and human populations, and they are the mechanisms by which pathogens in wild animals can infect domestic animals and people.

Since wild animals are the source, or reservoir, for so many important zoonotic pathogens, one important aspect of pathogen transmission is to consider the different ways in which wild animals can be the source of zoonotic infections for people. Pathogens can be transmitted from wild animals to humans by all of the routes of transmission just reviewed. However, zoonotic pathogen transmission also can be looked at in another way.



- This diagram tries to show the various relationships that can exist among wild animals, domestic animals and humans through which zoonotic pathogens from wild animals can be transmitted to humans.

- Pathogens from wild animals may be transmitted directly to people. Examples are *Brucella*, *Leptospira* and plague (*Yersinia pestis*)

- Pathogens from wild animals may be transmitted to domestic animals, which then become the source of infection for people. Examples are Nipah virus (from bats to pigs to people) and bovine tuberculosis (from wild animals to domestic animals to people).

- Pathogens from wild animals may be transmitted to domestic animals, undergo genetic changes in the domestic animal population, and then the genetically altered pathogen can be transmitted from domestic animals to people. An example is Highly Pathogenic H5N1 avian influenza virus which entered domestic poultry populations as a low pathogenicity strain from wild birds, developed into a highly pathogenic strain in domestic poultry and has been transmitted to people from domestic poultry.

- Pathogens may be transmitted from wild animals directly to humans, but then undergo genetic modifications within human populations that result in a new human pathogen which is maintained in human populations, is readily transmitted from person to person and no longer requires the original wild animal source to persist and continue to cause disease. Examples are HIV-AIDS, human pathogens derived from viruses in primate populations, and measles virus, a human pathogen very close to rinderpest virus and which became established in people through transmission from cattle, probably during the time when cattle were first domesticated.

VI. Reservoirs of infectious pathogens

In the above diagram of transmission of zoonotic pathogens, wild animals are shown as the source of zoonotic pathogens, which they very often are. In such situations, we often say that wild animals are the reservoir for these pathogens. Generally, what we mean by this is that the wild animals in question not only are the source of a zoonotic pathogen for infection in people or domestic animals, but also that these wild animals are the natural habitat for the pathogen. The pathogen is maintained and persists over time within these wild animal populations.

The majority of human and animal infectious pathogens are able to infect more than one species:

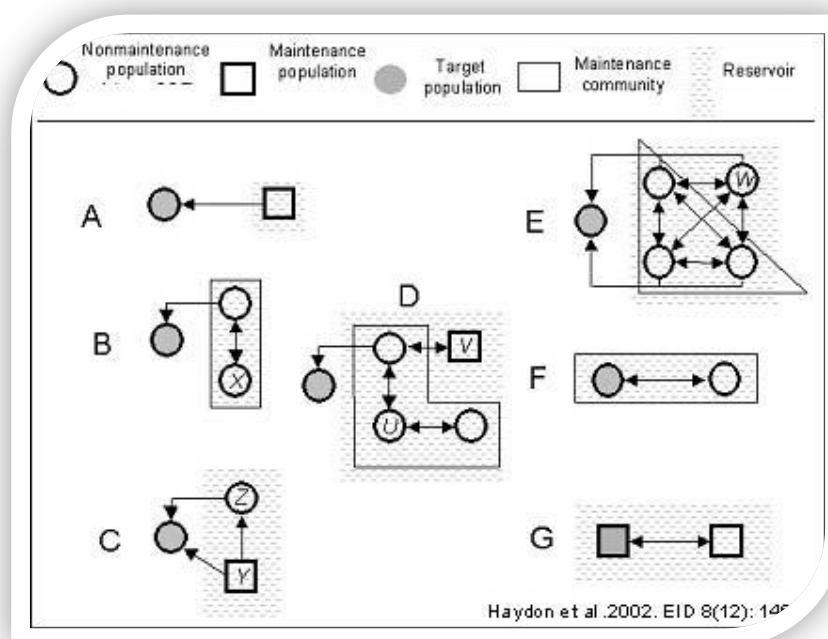
- 62% of all human pathogens are classified as zoonoses
- 77% of livestock pathogens infect multiple species
- 91% of domestic carnivore pathogens infect multiple hosts
- Nearly all pathogens that threaten endangered species around the world, like Chytrid fungi threatening tropical amphibians, infect multiple species.

Thus, many infectious pathogens may have reservoirs in other species from which they can be transmitted to the species of concern.

There are several different definitions of pathogen 'reservoirs' in the scientific literature. A paper published in 2002, Daniel Haydon and his co-authors offered a unified way of defining and understanding pathogen reservoirs that is very useful.

A pathogen reservoir is 'one or more epidemiologically connected populations or environments in which the pathogen can be permanently maintained and from which infection is transmitted to the defined target population'

We can look at this concept of a reservoir in diagrammatic form:



The reservoir of a pathogen for a target species of concern may be quite simple or quite complex. These diagrams show a range of possibilities. Circles represent populations that are not able to maintain the pathogen (non-maintenance populations) and squares represent populations that are able to maintain the pathogen (maintenance populations). The population of concern, the 'target population', is grey.

Figure A is the simple situation in which a single maintenance population is the source of infection for the target population and thus this maintenance population is the reservoir for the pathogen with respect to the target population. Examples include domestic dog populations as the reservoir for rabies in people in many parts of the world, or vampire bats as the reservoir for rabies in cattle. Hantaviruses and Arenaviruses similarly most often are transmitted to people from a maintenance host population of a single species of rodent.

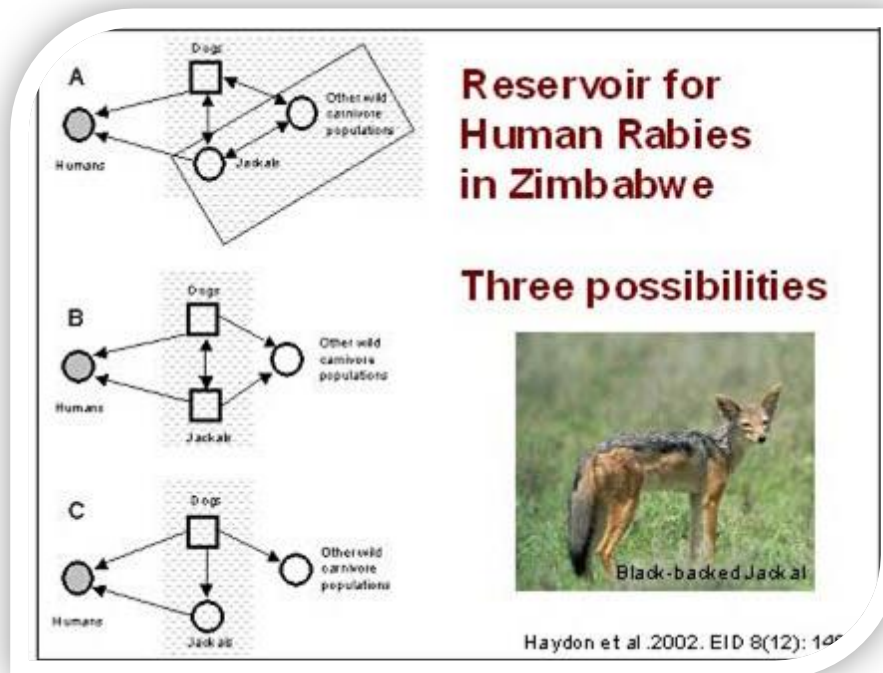
Figure B depicts a situation in which the reservoir of a pathogen consists of two different host populations, neither of which, alone, can maintain the pathogen but which do maintain the pathogen by transmission between the two populations. In this case, the reservoir is a maintenance community of two different species. This typically is the situation for vector-transmitted pathogens such as Yellow fever virus or West Nile virus. For these viruses, the maintenance community consists of non-human primates and several species of mosquitoes (Yellow fever) or a wide range of wild bird populations and several species of mosquitoes (West Nile).

Figure C depicts a situation in which the pathogen can be transmitted to the target population from two different animal populations, one of which is able to maintain the pathogen and one of which is not able to do so. Since the non-maintenance population is a source of infection for the target population, it is part of the reservoir for the target population even though it does not itself maintain the pathogen and is infected from the maintenance host. An example would be bovine tuberculosis in people, maintained in infected cattle populations but also infecting wild or domestic deer which often are not maintenance hosts. Infection can be transmitted to people from both the maintenance hosts (cattle) and non-maintenance host (deer) populations.

Figures D and E present ever more complex reservoir communities, consisting of collections of maintenance and non-maintenance hosts.

Figures F and G show that the target population also may be part of a maintenance community, and also may be a maintenance host in its own right. In both situations, the target host populations must be considered a part of the reservoir of the pathogen.

An understanding of the reservoir of a pathogen for a target population of concern can be critically important for designing and implementing control programmes to protect the target population. Consider the example of rabies in the African country of Zimbabwe, as discussed by Haydon and co-authors.



In Zimbabwe, the principal source of infection for people is domestic dogs, but jackals also are an important source of infection for people. There appear to be three different potential reservoirs for rabies with respect to people in Zimbabwe:

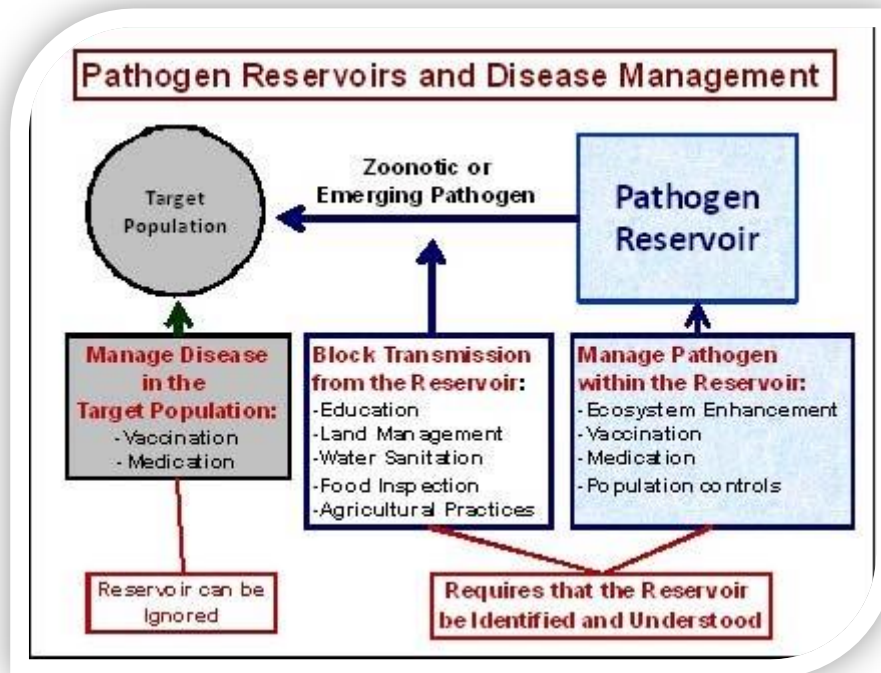
Figure A – here, dogs are the only maintenance host but virus also is transmitted to jackals and perhaps other wild carnivores. The jackals and the other wild carnivore populations are not themselves able to maintain the virus but, by transmission of virus from dogs to other wild carnivores and other wild carnivores to jackals, all are part of the reservoir of rabies for people. .

Figure C - is the same as A, except that other wild carnivores do not play any role in the reservoir of rabies for people.

Figure B - indicates that both dogs and jackals are maintenance hosts; each is able to maintain rabies virus within their populations independently, and each is an independent source of rabies for people.

Knowing which of these three possible depictions of the reservoir of rabies virus for people really is true has very important implications for preventing rabies in people. If either A or C is the true situation, vaccination of domestic dogs alone will control rabies infection in people. If Figure B is correct, vaccination of domestic dogs will not completely prevent rabies in people. An effective control programme would have to include control of rabies in jackals as well as in domestic dogs.

A correct understanding of pathogen reservoirs often is central to management of disease in the target population, especially for pathogens that occur in wild animals and can affect people or domestic animals.



Some disease control programmes focus on the target population, with vaccination or pharmaceutical treatment of the target population as the methods of choice. If this is the case, then it is not important to know the reservoir of the pathogen for people or even to know the principal routes of transmission. However, when control programmes are focused on preventing transmission of pathogens from the reservoir to the target population, or on controlling the pathogen within the reservoir, then a very precise understanding of the reservoir of the pathogen for the target population is required.

VII. The basic reproductive number ('R') - A measure of pathogen transmission

The concept of the basic reproductive number for a pathogen, symbolised by 'R' or sometimes 'R₀', is one of the most important concepts in disease ecology. The basic reproductive number of a pathogen is the number of new infections that will occur when an infected individual is introduced to a population.

R₀ is used to symbolise the basic reproductive number of a pathogen in the very particular situation when an infected individual is introduced into a population of individuals which have not been exposed previously to the pathogen and are totally susceptible to infection.

R₀: "The average number of secondary infections that occur when an infected individual is introduced into a population of susceptible individuals"

As an infection spreads, however, some individuals in the population recover and are immune, and the value of R changes. Since R₀ is a value when the entire population is assumed to be susceptible, the symbol R_{eff}, (effective value of R), or just R, sometimes is used to represent the true value of R at a particular time and place.

R₀ → R or R_{eff}
 (Time → → → → →)

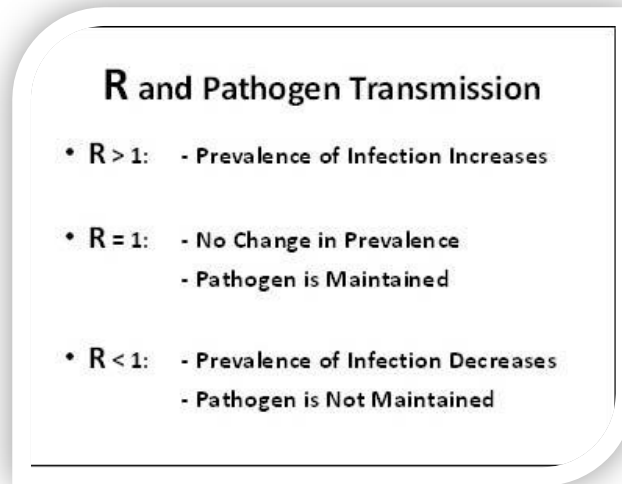
R is easiest to measure and to think about for pathogens that cause acute infections of a relatively short duration, such as small pox, measles, influenza, and Newcastle disease viruses. A population of animals or people which is infected with such acute pathogens will consist of three categories of individuals:

- susceptible to infection
- infected
- recovered and immune.

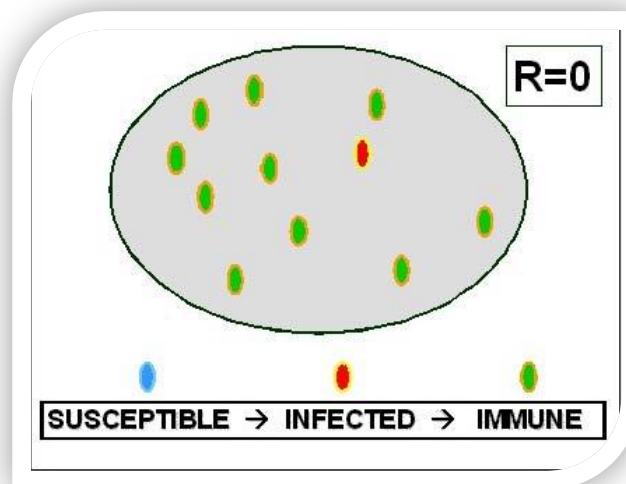
An individual animal (or person) starts out as susceptible to infection. If it becomes infected due to transmission of the pathogen from an infected individual, it either dies or recovers, and, if it recovers, is then immune to further infection.

R gives a numerical description of how a pathogen is transmitted within a population of host animals or people. If R = 1, then the number of infected individuals in the population will not change over time. Each infected individual will, on average, transmit the pathogen to only one other individual. For a pathogen to persist in a population, R must be 1 or greater (R ≥ 1). If R is less than one, (R < 1), there will be fewer and fewer infected individuals after each cycle of

pathogen transmission and recovery of the infected individuals. Eventually, transmission will cease and the pathogen will die out, will be eradicated.



The value of **R** for a particular pathogen and host species is not always the same. The value of **R** changes with the characteristics of the environment and of the host population, and it also can change during the course of a disease occurrence event. For example, in a population in which there is no significant immigration or emigration of host animals, or birth of new, susceptible individuals during the course of a disease event, the value of **R** will become smaller and smaller as an ever larger proportion of the population consists of individuals which have survived infection and are immune to further infection.



In such a situation, the pathogen eventually will die out when the last infected individual either dies or recovers from infection. All animals in the population now are immune. How long it takes for a pathogen to die out depends on the value of **R**. If **R** is only slightly less than 1, a pathogen may remain in a population for a long time - for months, years, or decades, depending on the situation. If **R** is much less than one, then the pathogen may die out quickly - in weeks or months perhaps. On the other hand, if new susceptible individuals are added to the population at a sufficient rate, **R** may never become less than 1, and the pathogen may persist forever in that population. Thus, birth rates, death rates, immigration and emigration rates can have a very large effect on the value of **R**.

The value of **R** distinguishes a population that can maintain infection with a particular pathogen over time ($R > 1$) from populations which cannot maintain a pathogen in the long term ($R < 1$). For example, measles in people generally has a very high **R** value when the virus is introduced into a susceptible population. **R₀** for measles is usually about 18! (Each infected individual on average will infect 18 other people before the individual dies or recovers from the infection). However, **R** quickly drops as the virus spreads rapidly through the population and in small human populations, measles dies out quickly. It is estimated that, to maintain measles virus, a human population of 300,000 to 500,000 in-contact individuals is required. In human populations of this size, there are enough births of new, susceptible individuals to permit pathogen transmission to continue and the virus to be maintained in the population.

R is very hard to measure directly. It usually is estimated by measuring a variety of other parameters over time and then using complicated mathematical formulas to estimate **R**. There is a scientific literature concerning **R** and its measurement or estimation, and thus there is good reference material available to guide those who need to estimate **R** for a pathogen in a particular host population and environment.

Estimates of **R** have great value in disease management programmes. **R** is especially valuable for planning vaccination campaigns aimed at eliminating a pathogen or reducing its impact. The objective of a vaccination programme is to increase the proportion of immune individuals in a population sufficiently to cause **R** to become less than one ($R < 1$), and thus to eliminate the pathogen from the population or greatly reduce its impact. If **R** can be estimated accurately for a given pathogen in a particular population, it is possible to estimate what proportion of the population must be vaccinated to achieve ($R < 1$). The formula is:

$$\text{Minimum proportion that must be vaccinated} = 1 - (1/R)$$

Actual R:	2	4	6	8	10
Must Vaccinate:	50%	75%	83%	88%	90%
(1 - 1/R)	of target animal population				

Small pox virus was eliminated from humans globally by vaccination campaigns based on careful estimates of **R**.

Infection	~R	Vaccination Campaign
Small Pox (Africa)	3.73	73% of Popn.
Small Pox (India)	5.71	83% of Popn.
Measles	18.0	94% of Popn.

VIII. Interventions to manage pathogens and diseases in wild animals

Introduction

In human medicine and in veterinary medicine applied to domestic animals, it is standard practice to use pharmaceutical agents, vaccination, sanitation, food inspection and other actions to prevent, treat and reduce the impact of infectious pathogens and diseases. However, this is not so for pathogens and diseases in wild animal populations. Standard medical techniques are difficult, often impossible, to apply to wild animals. When techniques such as vaccination or treatment with drugs are successfully applied to wild animals, each programme is preceded by years of costly research to develop and validate the techniques used and each requires years of very costly implementation to achieve the desired results. Most attempts to control pathogens and diseases in wild animal populations have failed; only a very few have succeeded.

There are four strategies that can be applied to management of pathogens and diseases in wild animals.

Before health issues arise from wildlife pathogens:

1. Prevent new health problems from arising.

After health issues from wild animal pathogens have emerged:

2. Take no action or response to the health issue;
3. Intervene to control the health issue to some degree;
4. Intervene to eradicate the pathogen of concern.

Many approaches have been taken to control or to eradicate pathogens from wild animal populations. These approaches have included:

- treatment with drugs delivered in oral baits or by remote injection
- vaccination: oral baits, remote injection, or trap-vaccinate-release
- reducing animal populations: reduced reproduction, translocation, killing
- changing animal distribution: fences, deterrents, attractants
- altering the environment: drainage, flooding, burning, insecticides.

Decisions on whether or not to attempt to control or eradicate pathogens in wild animal populations should be informed by a complete review of the control methods available and of the rationale and objectives of a control programme. Most often, there is little that can be done to control pathogens in wildlife populations, and the best choice will be to attempt to reduce the impact of such pathogens by actions that target the affected domestic animal or human populations.

- Separate domestic animals from infected wild animals;
- Vaccinate people and domestic animals;
- Focus on human behaviour:
 - cook meat
 - purify drinking water
 - prevent insect bites
 - control rodent populations around people.

Such programmes can significantly reduce transmission of wildlife pathogens to people and domestic animals, but do not require that disease management be attempted in wild animal populations.

1. Prevention

Countries should strive to have active programmes to prevent health issues arising from wild animal pathogens. Actions to prevent emergence of new health issues associated with wild animal pathogens are feasible and cost-effective. These should focus on the greatest risk factors associated with wild animal pathogens.

One such risk factor is the transportation, or translocation, of wild animals from one geographic area to another geographic area. The OIE Working Group on Wildlife Diseases has identified wild animal translocation as a particularly high-risk activity. Such wild animal translocations are carried out with high frequency world-wide. In one study of four countries, it was estimated that there were over 700 such translocations each year in 1986, and the trend in annual translocations was rising steeply (Griffiths *et al.* [1993]. – *J. Zoo Wildl. Med.*, **24** [3], 231). Health risk assessments carried out for such wildlife translocations are powerful preventive actions that can identify health risks and propose mitigation strategies to reduce or eliminate these risks. In 1999, the OIE Working Group on Wildlife Diseases developed a document to assist veterinarians, biologists, and wildlife service personnel to carry out health risk assessments for wild animal translocations (available at www.ccwhc.ca/wildlife_health_topics/risk_analysis/rskguidintro.php). Carrying out health risk assessments for all wildlife translocations, both international and within a country, is a major step toward preventing new health issues that every country can implement.

2. Health risk assessment in wild animal translocations⁷

Wild animals are moved from place to place for many different reasons. Most often, they are captured in the wild, transported, held in quarantine, and released again into the wild for conservation or wildlife management purposes. Sometimes this also is done for commercial purposes. There are potential health risks associated with all such movements of wild animals. The principal risks are:

- That the animals will carry pathogens into the destination environment that will cause harm to the destination environment.
- That the animals being moved will encounter pathogens in the destination environment and will be harmed by these new pathogens.

Health risk analysis can be carried out prior to the translocation of wild animals in order to determine:

- a) whether or not such risks exist, and
- b) the magnitude of the potential consequences, to the economy and ecology of the destination area and to the success of the translocation programme. The results of such risk analysis can then be incorporated into the final decision whether or not to proceed with the translocation. If the decision is to proceed but significant risks have been identified, the risk analysis can guide efforts to reduce risk.

⁷ From <http://www.ccwhc.ca/wildlife_health_topics/risk_analysis/rskguidintro.php>

3. Risk analysis process

Health risk analysis is a rigorous application of common sense to determine whether or not there are important health-related risks associated with a proposed activity, such as animal translocation. Risk analysis can be qualitative, in which risk is estimated as being negligible, low, medium or high, or it can be quantitative, in which mathematical models are used to give numerical estimates of the probability of a negative outcome and the economic, ecological and social harm that would occur as a result.

Wild animal health risk analysis usually will result in a qualitative assessment of risk. This is because, most often, there is not enough reliable numerical information about wild animals and their pathogens to support a reliable quantitative assessment of risk. Qualitative risk assessments are extremely valuable and can contribute as much or more to decision making and risk mitigation as can quantitative risk assessments.

The product of a risk analysis is a written report that documents all steps followed, all of the information considered and the way that information was evaluated.

4. Basic steps in health risk analysis in wild animal translocations

a) Translocation plan

A complete, detailed description of the translocation is made. This clearly defines the activity for which health risks are to be analysed.

b) Health hazard identification and selection for assessment

A complete, inclusive list of all potential health and related hazards is made. This step requires gathering of much information. If sufficient information is not available, this must be recognized and the risk analysis halted (see 'Information Requirements' below). From the complete list of potential hazards, the hazards that appear most important are selected for detailed consideration. Often, only a small number of hazards can be fully assessed. These must be chosen with care to represent the greatest potential for a harmful outcome.

c) Risk assessment

Risk is assessed for each major hazard selected. Risk has two parts:

- The probability that the health hazard will occur.
- The magnitude of the negative consequences if it does occur.

d) Overall risk assessment and statement of uncertainty

An overall assessment is made by combining the results of the assessments of each of the major hazards assessed individually. In every risk assessment, absence of certain information limits the precision of the assessment. A statement outlining important areas of uncertainty that have affected the risk assessment is written to give a complete picture of the strengths and limitations of the risk assessment.

e) Associated hazards and risks

Hazards that may not be directly related to health issues often become apparent during health risk analysis. A statement identifying these is written and included in the risk assessment.

f) Risk reduction

During a risk analysis, it may become evident that some of the risks identified could be reduced by changing procedures to be used in the translocation programme. A statement about ways in which risks may be reduced is included in the risk assessment.

5. Information requirements

Many different kinds of information are required for risk analysis: species and populations of animals, pathogens and their mechanisms of transmission and spread, transportation and quarantine facilities and procedures, and general information about the source and destination environments, including their human economies and cultures. If sufficient information is not available, it is not possible to carry out an analysis of health risks. Yet, very often, sufficient information is available to permit a health risk assessment that will contribute importantly to reducing risks and preventing wildlife-related disease problems.

6. Decision making

Decisions whether or not to proceed with wild animal translocations, or with other programmes that include wildlife health hazards and risks, may be determined by the results of health risk analysis, but they also may be influenced by a variety of other factors. Risk analysis informs decision makers regarding health risks and provides them with options to reduce risk if it is decided to proceed with the translocation or other programme.

7. Objectivity, subjectivity and transparency

Health risk analysis must be as objective as possible. It should be based on all of the available, relevant information and firmly on science. However, it is not possible to conduct a health risk analysis that is entirely free of subjective judgement. It is possible and essential, however, to identify clearly when a subjective judgement is used within a risk analysis. The basis for such judgements should be clearly stated so that there can be no confusion by the reader of the risk analysis report regarding which elements of the analysis are based on science and which are based on subjective assessments. Thus, health risk analysis must be transparent. The reader of a health risk analysis report must be informed of all of the information that was available to the analysts, must be shown how the information was evaluated and how risk assessments were derived, must be informed of information that was not available or that was ignored, and must be informed of the uncertainties associated with the risk analysis.

IX. Components of a national wildlife disease programme

1. Rationale for a national wildlife disease programme

Every country needs a set of government policies, regulations and programmes to enable it effectively to manage issues associated with pathogens in wild animals. In the past few decades, issues associated with pathogens in wild animals have increased in number and magnitude world-wide. Countries which are not prepared to manage these issues are at increasing risk of experiencing significant impacts from these health and disease issues.

National wildlife disease programmes generally have two primary objectives. The first objective is to reduce the social, human health, economic and ecological costs to society of pathogens in wild animals. As noted previously, there are many potential socio-economic costs associated with pathogens in wild animals:

**Wildlife Pathogens:
Socio-economic Significance**

- **To Human Health**
 - Zoonotic Pathogens
 - Food Safety (wild animal products)
- **To Domestic Animal Health**
 - Pathogens Shared with Livestock, Poultry
 - Economic Costs to Livestock Industries
 - Effects on Human Food Supply & Food Safety
- **To Wildlife and Environmental Health**
 - Economic costs - Harvest, Tourism
 - Environmental Costs – Biodiversity, Stability

A national wildlife disease programme is intended to reduce these risks through active assessment and management.

The second objective of a national wildlife disease programme is to meet international obligations to detect and report important pathogens that are present in wild animals. This obligation has become increasingly important in recent decades because of the exponentially increasing numbers of emerging diseases and related issues, many of which arise from pathogens in wildlife. Every country wants to know about potential health threats elsewhere in the world. The only way this information will be made available is through agreements among countries to participate in international disease reporting programmes. Thus, the member countries of three international organizations, the OIE, WHO and FAO, have made agreements to

report occurrences of certain human and animal pathogens when they occur in any species. All also have agreed that international reporting of pathogens in animals, including wild animals, will be done through the OIE, system.

Thus, each country needs a national wildlife disease programme to meet its obligations for international reporting of diseases, as well as to reduce costs and harm to its own society.

2. Components of a national wildlife disease programme

National wildlife disease programmes must be programmes coordinating several different components and activities, each of which is essential to the programme as a whole. Four essential components of such national programmes are these:



a) Prevention of new issues associated with wild animal pathogens

It is far better to prevent a problem associated with wild animal pathogens than to manage the problem afterward. Preventive programmes will have several components. One is effective border control to prevent import and export of pathogens in wildlife. Effective border controls require that global health and disease issues be monitored and reported internationally so that countries are aware of current health risks associated with importations of wild animals. As noted earlier, health risk assessment for all movements (translocations) of wild animals is a critically important component of preventive programmes. Wildlife pathogens already present in a country also may be the source of new health issues. Disease emergence often is associated with changes in land use, for example. Thus, another component of prevention of new health issues associated with wild animal pathogens is assessment of emerging disease risks in a wide range of national social and economic programmes.

b) Early Detection of wild animal pathogens or the diseases they may cause

Early detection of a pathogen new to a country, or of a new pattern of disease caused by a pathogen already present, is very important for effective disease management. Early detection permits early assessment and decisions about whether or not to respond with management actions, and management actions taken early in a disease event are more likely to succeed and cost less than management actions taken at a later time. Pathogen detection requires a national programme of wildlife pathogen surveillance, with many wild animal specimens examined every year.

c) Timely decisions and responses to wildlife pathogens

This is a major challenge for national governments. Responsibility for responding to pathogens in wild animals often is poorly defined within government structures and processes. Often, it is not clear which branch of government is responsible for such responses: Health? Agriculture? Environment? Thus, a national wildlife disease programme requires a governance structure that involves all relevant branches of government and is capable of deciding, for each wildlife disease occurrence of potential importance, whether or not a response is required and, if so, which of the branches of government will participate in the response. Usually, new government policies, new decision-making agreements and new cost-sharing agreements among different branches of government are required in order to succeed with this component of the national programme.

d) Effective wildlife pathogen management

While most pathogens in wild animals require no management actions, countries must be prepared to manage pathogens in wild animals when these pathogens pose significant socioeconomic problems. Effective management interventions to control wildlife pathogens require advance planning based on a range of potential response scenarios. Such planning must identify the management actions that can be taken, and the tools (e.g. education, vaccination, environmental management) that are available. Such planning must also make use of the best available scientific knowledge and be revised regularly as relevant knowledge increases. Such planning may require investment in scientific research to obtain new knowledge required to answer key questions essential to response planning.

These four essential components of a national wildlife disease programme need to be supported by two other key programme components: Communication and Education.

Communication: A carefully developed, comprehensive communications plan is required to ensure that all components of the national programme are coordinated and function together. Without this, a national programme will fail. The communications plan must include both internal communications which connect and coordinate the programme itself, and external communications through which the programme speaks with one voice to government officials and to the public.

Education: A national wildlife disease programme cannot function unless there are a sufficient number of properly educated people to work within the programme. Such required personnel include technical personnel with knowledge and skills specifically in wildlife pathogens and diseases, wildlife biologists, wildlife veterinarians, disease ecologists, epidemiologists, and laboratory diagnostic specialists. Thus, universities, technical colleges and government ministries of education need to be participants in a national wildlife health programme.

X. Wildlife disease surveillance

1. Wild animal pathogen surveillance is essential to animal health management

Surveillance for wild animal pathogens is the single most important component of a national wildlife health programme. It is essential to all of the other components. For OIE Wildlife Focal Points, it is the activity of greatest importance because it provides all of the information the focal point needs to carry out his or her work.

Only through wildlife pathogen surveillance can a country know what pathogens exist within its wild animal populations, in which geographic areas and in which host species. Surveillance is required to detect new, emerging diseases. Surveillance also can measure the proportion of animals in a population which are infected. All of this information is required to assess health risks associated with international trade or internal movement of wild animals, and to meet international obligations for disease reporting.

Surveillance also requires an organised system of observation of wild animals in the field, veterinary diagnostic laboratories, information management systems and communication systems, all of which also are required when a country decides to respond to a disease outbreak and take management actions. Thus, surveillance can build the national capacity that also is required to manage urgent animal health events.

Surveillance is 'the systematic on-going collection, collation, and analysis of information related to animal health and the timely dissemination of information to those who need to know so that action can be taken.' (OIE *Terrestrial Animal Health Code*).

The key points are:

- 1) That it is a continuous activity, a constant investigation and vigilance for pathogens in wildlife and the diseases they may cause;
- 2) That surveillance involves not just the collection of information but also the regular analysis of the data for specific purposes; and
- 3) That surveillance includes communication of the results of data collection and analysis to the full range of people, agencies and institutions that need the information. Thus, a surveillance programme has several different components:
 - i) detection of dead or diseased wild animals, or collection of samples from wild populations
 - ii) identification of pathogens and diseases (diagnosis, laboratory tests)
 - iii) information management: computerized records of all information
 - iv) data analysis and communication: maps, statistics, reports, risk analysis, meetings



2. Forms of pathogen and disease surveillance

The many aspects of animal health surveillance are described in Chapter 1.4 of the OIE's *Terrestrial Animal Health Code*. However, some aspects of pathogen and disease surveillance in wild animals require special attention. In wild animal populations, probability-based sampling methods (*Terrestrial Animal Health Code*, Chapter 1.4.4) seldom can be used because of practical problems of access to wild animals and lack of accurate information about population sizes and structures. Thus, most samples in wildlife pathogen surveillance will be non-random and will be based on what is possible to achieve given the difficulties of securing samples from wild populations (often called 'convenience sampling'). This will affect the analytical approaches that can be applied to the surveillance data and the nature of the conclusions that can be drawn from the data. Nonetheless, such surveillance remains a powerful and essential tool in national and international management of animal and human health, and should be carried out in every country.

There are two quite different forms of pathogen surveillance. One is general or scanning surveillance (also sometimes called 'passive' surveillance, although there is nothing 'passive' about such surveillance programmes) and targeted surveillance focused on a particular pathogen in specified wild animal populations (sometimes also called 'active' surveillance). Both forms of pathogen surveillance are required in a national wildlife health programme.

3. General (scanning) surveillance for pathogens in wild animals

General or 'scanning' wildlife pathogen surveillance is the most important component of a national wildlife health programme. It is not possible to have a complete national animal health programme unless a country has a programme of general wildlife pathogen surveillance. General surveillance is the only way a country can know what pathogens exist in its wildlife, and it is the only available form of national vigilance for emerging diseases associated with wild animal pathogens.

4. Components of a general surveillance programme for wildlife pathogens

As noted earlier, wildlife pathogen surveillance consists of four very different activities which must be tightly coordinated into a cohesive surveillance programme. Each of these four components involves different people with different training and expertise and, often, from different branches of government or from non-government organizations or universities.

a) Detection of pathogens and diseases in wild animals

General surveillance for wildlife pathogens and diseases most often begins with detection of sick or dead wild animals. Most general wildlife pathogen surveillance programmes are based on examination of wild animals found dead. Therefore, dead wild animals are the most important resource to the surveillance programme. Thus, the first component of a general surveillance programme for wildlife pathogens is a network of people who are likely to encounter dead or sick wild animals. These same people or others must be prepared to collect these dead wild animals and transport them to an animal disease diagnostic laboratory, or they must be trained to dissect such animals in the field and send the correct samples to the laboratory.

Who can carry out this work? The answer to this question may differ among countries, but a successful programme will require a network of people who spend time in areas inhabited by wild animals and who are informed how to report dead or sick wildlife to authorities who will ensure that specimens are sent to an appropriate laboratory. Thus, those persons responsible for wildlife pathogen surveillance must recruit the interest and cooperation of a wide range of people who spend time in wild animal habitats. Such people include, particularly, government wildlife officers and biologists, usually associated with ministries, departments or agencies (federal, state/province, regional) responsible for wildlife management. These people require permission and encouragement from their employers to participate in the surveillance programme. Other potential participants include hunters, fishermen, naturalists, university scientists, non-government conservation organizations, and the general public. To obtain their participation in the surveillance programme, such people must regularly be informed about the programme, encouraged to participate and rewarded for doing so. They may require assistance, such as free telephone access to surveillance programme staff, special training sessions, and sometimes also financial assistance, and should receive reports on the results of the surveillance programme to maintain their interest and collaboration.

Those responsible for the wildlife pathogen surveillance programme will need to spend time and resources every year to maintain and support this network of people engaged in detection of sick or dead wild animals and the transport of specimens to laboratories.

b) Identification of pathogens and diseases

Once dead or diseased wild animals are detected, they must be examined to determine why they are sick or dead, and what pathogens they may carry.

Who can carry out this work? This work can only be carried out by well-trained animal pathologists in fully-equipped animal disease diagnostic laboratories which also employ well-trained microbiologists, molecular biologists, parasitologists and toxicologists. Such laboratories must be capable of identifying a wide range of viral, bacterial, protozoal, fungal, and metazoan infectious pathogens and also a wide range of toxins and environmental contaminants and poisons. Such laboratories most often are associated with a country's government ministry, department or agency responsible for agriculture, domestic animal health and Veterinary Services. Thus, the ministries or agencies responsible for wildlife and the ministries or agencies

responsible for veterinary diagnostic laboratories usually must collaborate closely in any wildlife pathogen surveillance programme.

Laboratory tests for wild animal pathogens:

There is a wide range of different kinds of tests used to identify pathogens in animals. Examples include culture for bacteria, fungi and viruses, polymerase chain reaction (PCR) tests for many different pathogens in tissues and fluids, intradermal skin tests in living animals, enzyme-linked immunosorbent assays (ELISA) for antibodies or for pathogens (antigens), and several other tests for antibodies against various pathogens.

All of these tests can produce false results. The error inherent in such tests often is measured and expressed as the sensitivity of the test and the specificity of the test.

Sensitivity: The proportion of truly positive animals that are correctly identified as positive by the test. [For example, if 100 infected animals are tested and the test results are 80 positive animals and 20 negative animals, the sensitivity of that test is 80%]

Specificity: The proportion of truly negative animals that are correctly identified as negative by the test. [For example, if 100 uninfected animals are tested and the test results are 15 animals infected and 75 animals uninfected, the specificity of the test would be 75%]

Perfect diagnostic tests would be 100% sensitive and 100% specific. However, many diagnostic tests have much lower sensitivity and specificity. Some are as low as 30%. Thus, it is important that the sensitivity and specificity of diagnostic tests be known and surveillance results interpreted accordingly. Unfortunately, the sensitivity and specificity of a test may change greatly depending on the host animal species to which it is applied. Most diagnostic tests are developed to test for a pathogen in one or a small number of domestic animal species. Much work goes into perfecting the tests for these species. However, when applied to other species, these same tests may have much lower specificity and sensitivity, or may be completely invalid and provide only false test results. This is a major concern in surveillance for pathogens in wild animals. Some tests are not much affected by the species of host animal, but other tests are valid only for the species of host animals for which they were developed and validated.

For example, conventional ELISA tests for antibodies to many pathogens must be developed and validated separately for each individual species of host animal on which the test will be used. Unless this is done, the results of the tests are meaningless. Indirect and blocking ELISA tests, on the other hand, do not depend on host-specific reagents and can be more widely applied. The tuberculin skin test has a sensitivity in cattle (*Bos taurus*) of about 85%, but in American Bison (*Bison bison*), a member of the same Family (Bovidae) as domestic cattle, the sensitivity is about 67%, and in the deer family (Cervidae), results are quite erratic and unreliable.

Thus, great care must be taken in wild animal pathogen surveillance to ensure that the tests used to identify pathogens in wild animals are valid and can be applied to the wild animal species under study. Furthermore, the specificity and sensitivity of the diagnostic tests used must be included in the analysis and interpretation of the surveillance results. For example, if a population of wild animals is tested for a particular pathogen using a test with a sensitivity of 100% and a specificity of 90%, and if it is determined from a large sample of animals that 5% of the animals tested are infected, it must be recognized that there is a reasonable probability that population is not infected at all; all of the positive test results may be false positive results since false positive results are expected in 10% of the animals tested.

c) Information management

The third component of pathogen surveillance is management of all of the information produced from the activities of Detection and Diagnosis. Information must be managed so that:

- 1) all the surveillance data are incorporated,
- 2) surveillance data can reliably be searched, retrieved and analysed,
- 3) surveillance data can be mapped, and
- 4) surveillance data are securely archived and preserved over time.

Who can do this work? Creation, maintenance and on-going development of a computerized data management system for pathogen surveillance requires a small group of people expert in information technology and, specifically, database design. They must work closely with the people who create the information (detection and diagnosis) and the people who will use the information (analysis and communication) so that the information management system serves the total needs of the surveillance system. Several wildlife pathogen surveillance information management systems have been developed around the world and countries which do not already have such a system may find it helpful to seek assistance from the developers of these databases currently in use.

Information management is critically important to pathogen surveillance. It requires dedicated full-time personnel and continuous modification as the standards and tools of computing and data management change over time. The information management system usually can be designed to serve the needs both of general surveillance and also of targeted surveillance. Through the Internet, it now is feasible and affordable to create a central information management system that can be used by all participants in the surveillance programme in all parts of a country.

d) Analysis of Data and Communication of Results

The fourth component of pathogen surveillance is analysis of the data produced by detection and diagnosis, and communication of those results to those who need this information.

Who can do this work? Analysis and interpretation of wildlife pathogen surveillance data requires the combined expertise of wildlife biologists, wildlife pathogen and disease specialists, epidemiologists and communications specialists. Each of these areas of expertise is required to correctly interpret the results of wildlife pathogen surveillance and to transmit the information to others. Thus, the surveillance programme must include a small team of people expert in these fields and who understand the purpose of the surveillance programme.

Who needs wildlife pathogen surveillance information? Information on wild animal pathogens generally is required in four areas of public responsibility:

1. public health
2. domestic animal Health
3. wildlife conservation and management
4. environmental management.

Analysis of surveillance data must serve all four of these areas, and the concerns and interests of each often are very different. For example, public health agencies will want to know about zoonotic diseases and food safety. Veterinary Services will be concerned about pathogens shared with domestic animals and potential implications for food production, agricultural economics and international trade. Wildlife conservation agencies will be concerned about potential effects on wild animal populations and potential conflicts between wild animal

populations and human activities. Environmental managers will be concerned about the stability and resilience of ecosystems and detection of toxic chemicals or other environmental contaminants. In addition, the public will expect to be informed accurately and immediately, whenever pathogens in wild animals create a significant risk to themselves, their animals or their environment, including wildlife.

Thus, a small team of analysts and a complete communications protocol that serves the needs of all branches of government and the public is required as a part of any surveillance programme for wild animal pathogens.



The communications protocol should include a range of different forms of communication, each intended to fill a particular need, as outlined in the figure above.

5. Components of a targeted wildlife pathogen surveillance programme

Targeted pathogen surveillance is done to obtain information about a particular pathogen in a particular host animal population or community: for example, to determine if West Nile virus is present in an area, or to determine what proportion of a population of wild ungulates is infected with Foot and Mouth Disease. Sometimes it is done to trigger a disease management action as soon as the pathogen is detected. Sometimes it is done to establish that a pathogen is not present in a susceptible wild population so that a country can claim that it is free of a particular pathogen.

Targeted surveillance differs from general surveillance in that it seeks to measure the presence of only one pathogen and that samples sometimes can be collected according to a statistical or probability-based sampling plan. Thus, standard epidemiological statistical estimates and analyses can more readily be applied to the surveillance data than is the case with general or scanning pathogen surveillance.

An important aspect of targeted surveillance is planning the way in which samples will be collected and tested. This plan will be determined by the purpose for which the targeted surveillance programme is being carried out. It is essential that an epidemiologist or statistician participate in planning the sampling and testing programme so that the results will be suitable for the kinds of analyses required. The sensitivity and specificity of the diagnostic tests to be used in the animal species included in the programme must be included in the statistical component of the plan. Statistical sampling of wild animal populations often is compromised by lack of the required information about the size, age and sex structure and precise geographic

distribution of the wild animal population of interest. Sampling also is compromised by the practical difficulties associated with obtaining samples from wild animals. Thus, fully statistical, probability-based sampling cannot always be achieved, and estimates of prevalence of infection or geographic distribution of infected animals will be less precise than is expected in surveillance of pathogens in domestic animals or humans. Nonetheless, much important information can be obtained through targeted surveillance in wild animal populations.

The basic elements of a targeted surveillance programme are the same as for a general pathogen surveillance programme. Detection of pathogens is achieved through planned sampling of a particular population of wild animals rather than through samples of opportunity. Identification of pathogens, information management and analysis and communication of results are the same in both forms of pathogen surveillance.

Strengths and limitations of targeted pathogen surveillance

- **Strengths:** - Statistical, probability-based sampling sometimes is possible.
- May permit statistical estimates of prevalence, geographic distribution
- **Limitations:** - Tests for only one pathogen
- Does not detect new pathogens or emerging diseases

6. Special problems with pathogen surveillance in wild animals

There are some particular difficulties and challenges associated with wild animal pathogen surveillance compared to surveillance in domestic animals or in people.

a) Government structure and wild animal pathogens

Within most governments, responsibility for managing pathogens and diseases in wild animals is not clearly assigned. Often, certain pathogens are the responsibility of ministries of agriculture and their Veterinary Services, others are the responsibility of ministries of health. Responsibility for managing wild animal populations often is the responsibility of ministries of environment or forestry or fisheries. Under these circumstances, there often is confusion as to which branch or branches of government should be responsible for wildlife pathogen surveillance. Under such conditions, it is difficult for government agencies to develop a surveillance programme and find the resources required to operate the programme. Thus, successful programmes of wildlife pathogen surveillance most often are achieved through inter-ministerial or inter-departmental collaborations which agree on objectives and define the role of each relevant ministry or department. Universities and non-government organisations can greatly assist such programmes by providing expertise and by facilitating collaboration among ministries.

b) Detection of disease

Detection of dead or diseased wild animals is very difficult. Sick people identify themselves to health care systems, and owners of domestic animals observe them closely and readily detect illness. But, in General Surveillance of Wildlife Pathogens, detection of disease requires time, resources and continuous effort. In targeted surveillance, obtaining the desired samples often is very challenging and requires both careful planning and adequate resources.

c) Host species diversity

There are many different species of wild animals. Each is unique in its physiology, its life habits, its population dynamics and its pathogens and diseases. This diversity of host species poses challenges for pathogen surveillance in wild animals. One big challenge is the correct identification of the species of host animal. This is never a serious problem in human or veterinary medicine applied to conventional domestic species, but it is a major challenge with wild animals. Yet it is critically important that host animal species be correctly identified in surveillance programmes for wild animal pathogens. The expertise to do so, and to train others to do so, exists in ministries responsible for wildlife, in universities and in naturalist organizations. This expertise must be incorporated into programmes of surveillance for pathogens in wild animals.

Appendix 1

Terms of Reference for the OIE National Focal Point on Wildlife

During the 76th General Session of the World Assembly of National Delegates in May 2008 the importance of the focal point for information on animal diseases was re-iterated and Delegates were also requested to nominate additional focal points for wildlife, veterinary products, animal production food safety, animal welfare and aquatic animal diseases.

As detailed in the final report of the General Session, the responsibilities of the focal points are under the authority of the OIE Delegate. Any information transmitted to the OIE from the different focal points needs to be transmitted under the designated authority of the OIE Delegate. This practice would equally apply, if focal points are located in other Departments or Ministries not under jurisdiction of the Veterinary Authority, as from a legal perspective the OIE considers the official OIE Delegate to be the unique representative of the country.

Details on proposed tasks of the national focal point for wildlife:

1. to establish a network of wildlife experts within his country or to communicate with the existing network;
2. to establish and maintain a dialogue with the Competent Authority for wildlife in his country, and to facilitate cooperation and communication among several authorities where responsibility is shared;
3. under the authority of the OIE Delegate of his country, to support the optimal collection and submission of wildlife disease information to the OIE through WAHIS (immediate notifications and follow-up reports, six-monthly reports, and annual questionnaires) to enable the OIE Delegate to more efficiently manage his OIE Member obligations;
4. to act as a contact point with the OIE Animal Health Information Department and the Scientific and Technical Department on matters related to information on wildlife including wildlife diseases;
5. to receive from the OIE Headquarters copies of the reports of the Working Group on Wildlife Diseases, selected reports of the Scientific Commission for Animal Diseases and other relevant reports, should they address discussion points on wildlife or the livestock-wildlife interface and conduct the in-country consultation process with recognised wildlife and animal health experts on draft texts of standards proposed in those reports as well as draft standards proposed by the Terrestrial Animal Health Standards Commission when dealing with wildlife diseases; and
6. to prepare comments for the Delegate on each of the relevant meeting reports reflecting the scientific view and position of the individual OIE Member and/or the region including comments on the proposals for new OIE standards and guidelines related to wildlife.

Appendix 2

Project for small groups

(to be distributed to the participants of each Group at the beginning of the specific session)

Wildlife pathogen and disease surveillance

Your project is to design 2 different programmes of surveillance for wildlife pathogens and diseases in your home countries.

1) A programme of general, scanning surveillance for diseases of all wild and free-roaming (not captive) terrestrial vertebrate animals (mammals, birds, reptiles) in your country

The objectives of this General Surveillance programme are:

- a) to determine what pathogens and diseases are present in wild animals
- b) early detection of new pathogens and diseases in wild animals
- c) to gather the information required to report on the presence of pathogens and diseases in wild animals to the OIE
- d) to provide information about pathogens and diseases in wild animals to your OIE Delegate and others who are responsible for wildlife management, agriculture and public health.

2) A programme of surveillance specifically for avian influenza viruses in wild ducks. (A targeted surveillance programme)⁸

The objectives of this targeted surveillance programme are:

- a) to determine the proportion of wild ducks which are infected with avian influenza viruses and to determine if this differs among duck species or among different regions of your country
- b) to determine if there are avian influenza viruses in wild ducks in your country which may cause disease or economic harm in people who raise chickens or other poultry.

What you will do: (see Instructions, on the following pages)

1. You will outline how each component of each surveillance programme could be organised in your country.

⁸ Note: In some workshops, instructors may choose to have participants design only one kind of disease surveillance program, in which case the General Surveillance program should be selected. If design of a Targeted Surveillance program also is done, instructors may wish to select a different pathogen, for example rabies virus instead of avian influenza viruses, depending on the pathogens of importance in the region of the workshop

2. You will compare your outline with those of the others in your group to determine how the organisation of various components of surveillance may be similar or different among the countries represented in your group.

3. You will choose one person in your group to make a short minute presentation of to all of the seminar participants about the programmes you have designed and the ways they are similar or different.

Schedule:

- work in small groups for 2.5 hours
- short reports to all participants will be made by each group.

Your report:

One person from each group should be prepared to give a short summary of how the general, scanning surveillance programmes and the avian influenza surveillance programmes would be organised in the countries included in your Group. Emphasize the main aspects that are the same among countries and the main aspects that are different among the countries

Procedure

- Appoint a discussion leader
- Appoint someone to take notes of the discussion
- Ensure everyone has an equal chance to speak

45 minutes: work individually to outline how the two surveillance programmes could be organized in your own country

45 minutes: compare your outlines and note the aspects that are similar and the aspects that are different among the different countries represented in your group

30 minutes: discuss and agree on the main points of the summary report to be presented

Instructions for designing the wildlife disease surveillance programmes

In planning your surveillance programmes, ensure that you plan for all components of each programme. Plan programmes that would be possible to achieve within your country, making use of the government agencies, universities, or non-government groups that already exist and could participate in such wildlife disease surveillance programmes

1. General, scanning surveillance for wildlife diseases

- Detection of pathogens and diseased wild animals
 - Who can find dead or diseased wild animals?
 - Who will go into the field to investigate these reports and secure dead animals or samples laboratory examination?
 - How will dead animals and specimens be sent to a laboratory?

- Laboratory identification (diagnosis) of disease in sick and dead wild animals
 - What laboratory(ies) can and will perform autopsy and other medical examinations and tests for pathogens and diseases in wild animals?
 - Where are these located?
- Information management
 - How can information about pathogens and diseases in wild animals be recorded, stored, searched and used in your country?
 - What systems now are used for domestic animal pathogens and diseases?
 - Can these same systems be used for wild animal pathogens and diseases?
 - What agencies or organizations would operate and maintain these recordkeeping systems (computer databases) for wildlife pathogens and diseases?
- Communication of surveillance results to meet the objectives of the programme
 - Who will review, analyse and report to the OIE Delegate and others about the results of the wildlife pathogen and disease surveillance programme?
 - What government agencies or others will be responsible for analysis and communication?
 - What government agencies or other groups will receive reports and information about the results of the surveillance programme?
- Management and governance of the programme
 - What government ministries or agencies will participate in this surveillance programme?
 - How will they be organised to work together?
 - Who (agency, group) will be responsible for coordinating and managing the programme to ensure that it meets its objectives?
 - Will there be important non-government participants?

2. Surveillance for avian influenza virus in wild ducks

- Securing samples from wild ducks⁹
 - Who will design the sampling plan to ensure that the results will be meaningful and valid statistically?
 - What information exists regarding the species of wild ducks, the size of their populations and their location throughout the year and in the various regions in the country? Who has this information?
 - How will wild ducks be captured for the survey and who will do this?
 - Who will correctly identify the ducks to species?
 - Where and by whom will the samples be frozen and then shipped to laboratory?

⁹ The samples needed for this survey are swabs taken from the mouth and the anus of live or freshly-dead wild ducks, placed in a vial of liquid medium, and frozen for transportation to the laboratory

- Testing of samples for avian influenza viruses¹⁰
 - What laboratory(ies) can and will perform the laboratory tests to detect and identify avian influenza viruses in samples from wild ducks?
 - Where are these laboratories located?
 - What OIE Reference Laboratories for avian influenza are available to assist or confirm results?
- Information management
 - How will the results of sample collection and laboratory tests be recorded, stored, searched and used in your country?
 - What agencies or organisations would operate and maintain these recordkeeping systems (computer databases) for avian influenza in wild ducks?
- Communication of surveillance results to meet the objectives of the programme
 - Who will review, analyse and report to others about the results of the survey for avian influenza in wild ducks?
 - What government agencies or other organisations will be responsible for analysis and communication.
 - What government agencies or other groups will receive reports and information about the results of this avian influenza surveillance programme?
- Management and governance of the programme
 - What government ministries or agencies will participate in this surveillance programme for avian influenza in wild ducks?
 - How will they be organised to work together?
 - Who (what agency or group) will be responsible for coordinating and managing the programme to ensure that it meets its objectives?
 - Will there be important non-government participants?

¹⁰ Samples can be tested by PCR, or by virus culture and identification



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