We often think of human, veterinary and wildlife medicine as separate disciplines, but this distinction makes little sense when we consider the epidemiology of infectious diseases. Most pathogens that cause human and animal diseases are ecological generalists – they can infect and be transmitted by more than one host species – and for many, the spectrum of hosts includes wildlife species. This is true for almost half (44%) of all pathogens that cause human diseases and 70% of the pathogens that cause the most internationally important veterinary diseases (e.g. rinderpest, foot-and-mouth and avian influenza).

**Multi-host pathogens and emerging infectious diseases**

Although we know very little about the dynamics of infectious agents in most wildlife populations, wildlife hosts appear to play a key role in the emergence of human and domestic animal diseases. A recent analysis has shown that pathogens that can infect wildlife are more than twice as likely to cause emerging diseases (in both humans and livestock) as those that do not affect wildlife. This includes newly recognized pathogens, such as HIV-1, HIV-2, BSE, Hendra virus, Nipah virus and the SARS coronavirus, as well as those that are spreading (re-emerging), such as rabies and West Nile virus.

Although we currently lack denominator data on wildlife diseases (and hence cannot quantify risk factors for emergence), pathogens that infect several host taxa have also been responsible for most emerging wildlife epidemics, including several that have threatened endangered species, such as rabies, which decimated populations of the Ethiopian wolf (one of the world’s rarest carnivores) and canine distemper, which has caused major declines in Channel Island foxes and Lake Baikal seals. Generalism appears to be a common characteristic of emerging pathogens, whether in human or animal populations.

Several factors may underlie disease emergence, but in practice, most emerging human diseases are associated with ecological changes, such as changes in land-use, environment, climate, human demography or animal and human movement patterns. Many of these factors can lead to increased human–wildlife contact and thereby facilitate transmission of potentially pathogenic agents that are maintained in wildlife hosts. For example, deforestation and encroachment into new habitats have been linked with the emergence of California encephalitis virus, Ross River virus, Ebola and Marburg viruses (all of which co-infect wildlife).

**Human factors in emerging wildlife diseases**

For emerging diseases of wildlife, similar ecological and anthropogenic factors come into play. For example, the...
In summary, the links between infectious diseases of wildlife and human health poses several problems. First, the lack of knowledge of infection dynamics in wild animal populations limits the development of effective strategies for disease control. Even in the public health sector, disease surveillance is often not a high priority. In almost all wildlife populations, surveillance is rudimentary or nonexistent — and this is particularly true in the developing world where many emerging diseases have originated. Detection of pathogens in free-living wildlife is notoriously difficult, hampered by the enormous practical problems of finding, collecting and storing appropriate samples under field conditions, as well as the lack of species-specific diagnostic tests. Even where considerable investment has been made (as with bovine tuberculosis and badgers in the UK), the complexities of infection dynamics in multi-host systems make it difficult to identify optimum methods of control.

Second, even where wildlife hosts and/or reservoirs have been identified, the options for control in wildlife are limited. Many strategies, such as culling and creation of barriers, invariably result in harm to wild animals. Conventional approaches to disease control in animals, such as vaccination or treatment, have limitations in wildlife populations. Specific vaccines and treatments are often unavailable or untested for wildlife, and delivery in field settings is beset by logistic, financial and ethical considerations. The success of wildlife oral rabies vaccination campaigns in Europe and North America points a way to the future and has stimulated research into other non-lethal approaches, such as sterilization.

A third consequence of wildlife involvement in human diseases is the potential threat to the wildlife tourism industry. The economic damage caused by a decline in visitors to countries suffering from SARS and Ebola virus clearly highlights this problem. Equally clear is the important lesson learnt from the SARS epidemic about the need for open exchange and dissemination of epidemiological data. Balancing these needs presents a dilemma for wildlife managers, particularly in those countries dependent upon wildlife tourism for economic development. Additional dilemmas will invariably arise as molecular tools increasingly allow detection of pathogens in an expanding range of wildlife hosts. A major challenge for the future will be the epidemiological interpretation of these results and appropriate evaluation and management of potential disease risks.

In summary, the links between infectious diseases of wildlife and public health have far-reaching impacts and implications that pose considerable challenges to medical scientists, veterinarians and wildlife managers. To date, there has been little integration between these sectors — wildlife ecologists tend to show little interest in human health and public health scientists often have little knowledge of wildlife issues. But this interface provides exciting opportunities to develop innovative and collaborative approaches that will mitigate emerging disease risks for humans and minimize adverse impacts on wildlife.

■ Dr Sarah Cleaveland is a Lecturer in Tropical Animal Health at the Centre for Tropical Veterinary Medicine, University of Edinburgh, Easter Bush, Roslin, Midlothian, EH25 9RG, UK. Tel. 0131 650 6404; Fax 0131 651 3903 email sarah.cleaveland@ed.ac.uk

RIGHT AND BELOW: Recent wildlife epidemics of rabies and canine distemper in wild carnivores in the Serengeti, Tanzania, have been associated with a rapid expansion of domestic dog populations. PHOTOS SARAH CLEAVELAND

appearance of canine distemper as a devastating new disease in Serengeti lions has been associated with a rapid expansion of domestic dog populations living adjacent to the park; a marked increase in mycoplasmal conjunctivitis among passerine birds in north America has been attributed to habitat changes and artificial feeding; and the emergence of chytridiomycosis (a fungal skin disease), which has resulted in major population declines in amphibians in Australia and the Americas, has been linked to climate change and movements of captive amphibians.

While medical attention may focus on zoonotic risks from wildlife infections, disease risks from humans are a growing concern for conservationists. Disease transmission from both local people and tourists has long been recognized as a threat for wild primates — outbreaks of measles in mountain gorillas, polio and pneumonia in chimps and, more recently, Ebola in great apes have all been associated with human contact and proximity. However, human diseases are also emerging as threats to non-primate vertebrates, and recent outbreaks of Mycobacterium tuberculosis (presumed to originate from humans) have led to high mortality in meerkats and banded mongooses in southern Africa. With HIV/AIDS causing widespread immunosuppression in the human population and enhancing the potential for pathogen transmission, the risk of future wildlife outbreaks from humans must surely be set to increase.

● Implications of wildlife infections in the control of human emerging diseases

The link between wildlife and human health poses several problems. First, the lack of knowledge of infection dynamics in wild animal populations limits the development of effective strategies for disease control. Even in the public health sector, disease surveillance is often not a high priority. In almost all wildlife populations, surveillance is rudimentary or nonexistent — and this is particularly true in the developing world where many emerging diseases have originated. Detection of pathogens in free-living wildlife is notoriously difficult, hampered by the enormous practical problems of finding, collecting and storing appropriate samples under field conditions, as well as the lack of species-specific diagnostic tests. Even where considerable investment has been made (as with bovine tuberculosis and badgers in the UK), the complexities of infection dynamics in multi-host systems make it difficult to identify optimum methods of control.

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