*Rev. sci. tech. Off. int. Epiz.*, 2010, **29** (2), 329-350

# Disease risks associated with the translocation of wildlife

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**Summary**

Translocation is defined as the human-managed movement of living organisms from one area for free release in another. Throughout the world, increasing numbers of animals are translocated every year. Most of these movements involve native mammals, birds and fish, and are made by private and national wildlife agencies to augment existing populations, usually for sporting purposes. The translocation of endangered species, often to reintroduce them into a part of the historical range from which they have been extirpated, has also become an important conservation technique. The main growth in reintroduction projects over the last decade has involved smaller animals, including amphibians, insects and reptiles.

The success of potentially expensive, high-profile wildlife translocation projects depends to a large extent on the care with which wildlife biologists and their veterinary advisers evaluate the suitability of the animals and chosen release site, and on the ability of the translocated animals to colonise the area.

The veterinary aspects of reintroduction projects are of extreme importance. There are instances of inadequate disease risk assessment resulting in expensive failures and, worse still, the introduction of destructive pathogens into naïve resident wildlife populations.

In this paper, some of the disease risks attending wildlife translocation are described. Risk assessment, involving the examination of founder and recipient populations and their habitats, is now a pre-requisite of managed movements of animals.

**Keywords**

Conservation – Disease risks – Quarantine – Reintroduction – Translocation – Vaccination – Wild animals.

## Introduction

In recent years, the rate of global biotic impoverishment has greatly accelerated and is now said to be greater than at any time during the last 65 million years (93). Exponential human population growth and globalisation have led to even greater increases in the rate of consumption of natural resources and the loss of many species and their habitats (117). These direct impacts are compounded by the effects of climate change, which is now recognised to be the most important challenge for the 21st Century. The effects of this human-induced-change will cause massive shifts in animal distribution and undoubtedly accelerate species loss.

Unfortunately, very few National Parks and other designated protected areas were set up based on knowledge of ecosystem function and population genetics. In consequence, few are large enough to support adequate populations of key species without the risk of slow erosion of genetic variability. This situation can be alleviated by managing these systems as metapopulations and through regular reintroduction of fresh genetic material, either in

the form of live, individual animals from distant, unrelated sources or, indirectly, by using cryopreserved germplasm (semen and embryos). Although the latter is the preferred method for genetic management of domestic animal populations, its application in the wildlife arena remains experimental and has proven to be largely impractical and not cost-effective. In the field of conservation, the term 'translocation' is usually used to refer specifically to the 'intentional' movement of living organisms from one geographic area for free release into another, with the object of establishing, re-establishing or augmenting a population (50).

A survey (1973-1986) of intentional releases of indigenous birds and mammals into the wild in Australia, Canada, New Zealand and the United States shows that, on average, nearly 700 translocations were conducted each year (42). Native game species, many of them birds, accounted for 90% of these movements. Many similar releases, usually for sporting purposes, are made each year in Europe and on a smaller scale elsewhere in the world.

The risk of disease introduction by wildlife translocated from one part of the world to another for the companion animal and wildlife trade is probably of greater significance than the risk posed by animals translocated for sporting or conservation purposes. The inadvertent movement of infectious agents due to the wildlife trade involves human, domestic animal and wildlife pathogens (58). H5N1 type A influenza virus was isolated from two mountain hawk eagles illegally imported to Belgium from Thailand (106, 111) and in falcons moved for sporting purposes into and out of Saudi Arabia were implicated in the introduction of disease to the Kingdom (74). An assessment of the risks associated with importing birds into Europe resulted in a ban being enforced, primarily due to the perceived risks of the inadvertent importation of the so-called 'bird flu' virus (7, 34, 35). A paramyxovirus, highly pathogenic for domestic poultry, entered Italy through a shipment of psittacine and passerine birds from Pakistan for the companion animal trade (58). Monkeypox was introduced to a native rodent species, and subsequently to humans, in the United States by importing wild African rodents from Ghana for the companion animal trade (43). Chytridiomycosis, a fungal disease now identified as a potential cause of the extinction of amphibian species worldwide, has been spread by the international trade in African clawed frogs (*Xenopus* spp.) (115). A survey by the United States Department of Agriculture, carried out from November 1994 to January 1995, demonstrates the scale of the problem: 97 out of 349 reptile shipments from 22 countries (with a total of 54,376 animals) contained ticks (122). Ticks are vectors of some important diseases that threaten livestock and human health, including Lyme disease, heartwater and babesiosis. Wildlife are frequently important hosts for both the ticks and pathogens (83, 84). Translocation of animals from the wild to zoological collections is now a rare occurrence and even trans-continental shipments between collections are now uncommon, as these organisations manage breeding nuclei and maintain populations through national cooperative breeding programmes (59, 61, 65). Most of these organisations employ veterinary expertise and the collections are monitored closely for disease. Although still a possible route for transmission of novel pathogens this is a risk which is better managed now than in the past.

The risk of translocation of organisms through natural migration of wildlife is not discussed here nor is the risk from the movements of humans and their transport, but clearly the potential for disease transmission through wildlife migration routes exists, as recently demonstrated through work on migrating birds, arctic foxes and toxoplasmosis (91). Overall, the movement of human beings probably contributes the greatest risk of disease transmission globally.

The translocation of rare, endangered species for conservation purposes has also become more common, especially for species with limited dispersal ability, since such species often find themselves confined in shrinking and fragmented habitats where early extinction can be predicted (118).

Translocations of rare species can be expensive (20, 21, 60) and often attract great public attention (16). Several factors associated with the success of such projects were discussed and evaluated by Griffith *et al.* (42) but, surprisingly, the possibility that disease might have a negative influence on the efforts of founder animals to establish themselves was not considered. However, other authors have drawn attention to the problem (10, 12, 18, 22, 28, 40, 63, 67, 104).

# Types of disease risk

Most of the diseases likely to be of importance in translocation projects are infectious and many of them are a threat to biodiversity and human health (3, 29, 33). Other diseases of concern might arise through exposure to unfamiliar toxic plants or environmental hazards such as pollutants, or from physical injury or stress during the procedure. Whatever the objective of translocation, the risks involved will depend on a variety of factors. Among these is the epidemiological situation at the source from which the animals derive and at the destination or release site.

The source can be an aquaculture facility, a zoological garden, a ranch, an extensive breeding establishment or a free-ranging managed population. These can be local or sometimes located on a different continent from the recipient site.

The release site may be a National Park or other protected area or it may be suitable habitat in an undesignated area and in all these situations there will be contact with other wild species; often domestic livestock and humans are an added hazard. Whatever the origin of animals for translocation there is a risk of individuals carrying pathogens, but the greatest risk is likely in animals born and bred *ex situ* and maintained under artificial or unnatural conditions (zoological gardens, farms and ranches, captive breeding centres) (114). In natural populations *in situ* epidemiological processes and normal selection pressures will reduce the likelihood of pathogen persistence and healthy individuals are unlikely to be a high risk. They will not, however, pose zero risk, as they can be carriers of organisms that are potentially pathogenic in another species. *Ex situ* populations are likely to acquire local infections in these locations and, in some cases, become symptomless carriers of disease agents (e.g. gut colonisation with locally abundant nematodes). Animals kept outside of their range are often mixed with other species and as a result may be exposed to exotic pathogens from foreign countries and to infections transmitted by attendants and visitors. Furthermore, captivity or management of populations *ex situ* subjects species to unnatural and sometimes continuous stress, resulting in immunodepression and increased susceptibility to infection. Tuberculosis, usually of the bovine type in ungulates and of human origin in primates and elephants, is a good example of a disease which can be transmitted to stressed and susceptible translocated animals (Box 1). Between 1994 and June 2005, there were 34 confirmed cases of tuberculosis in elephants in zoological collections and National Parks in the United States. Thirty-one Asian and three African elephants were affected. *Mycobacterium tuberculosis* was the etiologic agent in 33 cases and *M. bovis* in one case (6). Tests based on multi-antigen print immunoassay and loop-mediated isothermal amplification, including penside tests (Chembio, Inc., United States) are now available for this disease and are being applied on captive wild animals in the United States and domesticated elephants in South Asia. These tests have high sensitivity and specificity; strain diagnosis still relies heavily on isolation and typing of the organism from cases (36, 87).

Ranch-raised or semi-captive animals, usually herding ungulates, are often exposed to the common pathogens of local domestic animals under extensive management. Tuberculosis, brucellosis, bluetongue and various tick-borne haemoparasitic diseases are common examples.

## Diseases introduced by translocated animals

It is clear, therefore, that any translocated animal, whatever its origin, can bring new pathogens into a release area, where they can cause disease among co-existing, immunologically naïve, wild and domestic animals.

As has been aptly remarked, a translocated animal is not the representative of a single species but is rather a biological package containing a selection of viruses, bacteria, protozoa, helminths and arthropods (77). Some of these, of course, may be non-pathogenic commensals and not necessarily a problem to the host or sympatrics.

**Box 1**
**Cryptic tuberculosis infection in ungulates presents a high disease risk with translocation**

Tuberculosis infection, exacerbated by the stress of translocation, occurred in semi-captive Arabian oryx (*Oryx leucoryx*) in Saudi Arabia (9, 36, 47). Although not a wild-to-wild or captive-to-wild translocation it was a significant movement of animals across a country for a high-profile captive breeding and release project. The problem had arisen from the mixing of mostly imported and captive-bred exotic wild ungulates with indigenous wildlife species in a large open pen near Riyadh over a number of years. It was not possible to pinpoint the species which introduced the infection to this collection, but the importation from Spain of a number of fallow deer (*Dama dama*), an animal highly susceptible to tuberculosis, was implicated. The veterinary care was sub-optimal and the presence of the disease was either unknown or suppressed for fear of recrimination by the owner. Before translocation the apparently healthy oryx herd was separated from the main enclosures, partly as a form of quarantine and partly to enable the animals to be trained in a fenced capture system for translocation. Over some months 57 apparently healthy animals were monitored and herded through funnels and crates daily until adapted to the process. On the designated day they were trapped in the crates in small groups and then flown to the new site in the National Wildlife Research Centre at Taif some 600 miles away and released into pens on fresh ground. The animals showed little sign of stress during the procedure but remained in close confinement in a small airspace for some 15 hours. It is likely some of these animals were sub-clinically infected with tuberculosis and some weeks later a number of the oryx became ill and died of tuberculosis. Despite the measures taken to reduce stress the translocation process was likely to have played a part in the outbreak of clinical disease. Fortunately this move was not for free-release, but it is a good illustration of the risk of using captive populations for reintroduction, the danger of cryptic infection for a translocation project, and the importance of extensive quarantine and screening.

There have been many instances in which animals have brought pathogens with them which have had a severe impact on wild and domestic stock in and around the release site (Table I). Some of these cases are well documented, such as the disastrous introduction of African horse sickness into Spain by two zebra (*Equus burchelli*) from Namibia in 1987 (80), and the translocation of wild turkeys (*Meleagris gallopavo*) between states in North America resulting in *Plasmodium* spp. being transmitted to extant wild turkeys (24). Single species mass mortalities amongst wild populations associated with disease introductions have been reported. In one such case the events were associated with herpesvirus brought in by sardine used in tuna (*Thunnus maccoyii*) feedlots in marine aquaculture schemes (39). Unfortunately, there are many more potential infections of fish, but the risks have largely been ignored in the movement of live fish globally. Many reports of disease outbreaks are only anecdotal or rudimentary and unconfirmed.

Capture and quarantine place a high level of stress on wild animals, particularly those caught in the wild (as opposed to those already living in captivity, which can be adapted to these conditions and management), and there is a great deal of variation in the response of species and age classes. Stress can lead to the clinical recrudescence of latent infectious diseases. For example, Cape buffaloes (*Syncerus caffer*) transported a long distance by lorry have excreted foot and mouth disease virus in sufficient quantities to infect cattle penned near the relocation site (46), and fatal cases of trypanosomosis have arisen in naïve black rhinoceros (*Diceros bicornis*) captured and translocated into infected areas (26, 62). In another report, a novel infection of a newly described *Babesia* spp. in black rhinoceros occurred in Ngorongoro crater at a time of stress (79). There is a possibility this pathogen was introduced with rhinoceros originating from South Africa that were released prior to this event, but the possibility was never fully investigated. Racoons (*Procyon lotor*) translocated in 1985 from Texas to West Virginia to augment the local racoon stock for hunting purposes are believed to have brought with them parvoviral enteritis, a serious disease previously absent in West Virginia and now enzootic to the

**Box 2**
**Warble and nostril fly introductions to Greenland**

In September 1952, 225 domestic reindeer (*Rangifer tarandus*) were translocated by ship from northern Norway to western Greenland, with the aim of providing a new livelihood for the local Inuit (95). Unfortunately, the reindeer brought with them a warble fly (*Oedemagna tarandi*) and a nostril fly (*Cephenemyia trompe*), both of which at that time did not occur in Greenland. In due course, these parasites began to affect the indigenous Greenland caribou (*R. tarandus groenlandicus*). Both flies severely harass the caribou throughout the relatively warm long summer days, so that the caribou are unable to feed sufficiently to build up the fat stores on which they depend to survive the Arctic winter. This translocation proved a disaster for Greenland caribou, which are now greatly reduced in numbers due to severe winter mortality. All caribou in western Greenland are now infested with the parasites. Another example, but in the opposite direction, was the spread of the giant liver fluke (*Fascioloides magna*) to European ungulates when infected wapiti (*Cervus elaphus*) were introduced into Italy from the United States (44).

**Table I**
**Diseases introduced into release areas by translocated wildlife**

| Translocated species | Origin | Disease/pest introduced | Release area | Affected species | Ref. |
|---|---|---|---|---|---|
| Zebra (*Equus burchelli*) | Namibia (w/c) | African horse sickness | Spain | Domestic equids | 80 |
| Racoon (*Procyon lotor*) | Texas (w/c) | Parvoviral enteritis | West Virginia | Local racoons | 1 |
| Racoon (*Procyon lotor*) | Florida (w/c) | Rabies | Pennsylvania, Virginia, Maryland | Skunks (*Mephitis mephitis*), local racoons | 4 |
| Wapiti (*Cervus elaphus*) | United States | Giant liver fluke *Fascioloides magna* | Italy | European ungulates | 44 |
| Reindeer (*Rangifer tarandus*) | Norway (c/b) | Warble and nostril flies (Box 2) | Greenland | Caribou (*Rangifer tarandus*) | 95, 96, 108 |
| Mojave desert tortoise (*Xerobates agassizii*) | Pet shops in California | 'Respiratory disease' (United States) | Mojave desert | Wild tortoise | 54 |
| Bighorn sheep (*Ovis canadensis*) | Arizona (w/c) | 'Viral pneumonia' | New Mexico | Local bighorns | |
| Plains bison (*Bison bison*) | Montana (c/b) | Tuberculosis, brucellosis | Canada | Wood bison (*B. bison athabascae*) | 5, 22 |
| Hare (*Lepus europaeus*) | Hungary and former Czechoslovakia | Brucellosis | Switzerland and Italy | Domestic animals, humans | 85 |
| Wild turkey | United States | *Plasmodium* | United States | Wild turkey | 24 |
| Sardine/Pilchard | Tuna feedlots, multiple origin | Herpesvirus | Australia | Sardine (*Sardinops sagax*) | 39 |
| Rainbow trout (*Salmo gairdneri*) | United States (c/b) | 'Whirling disease' | United Kingdom | Trout | 109 |

c/b: captive bred
w/c: wild caught

local racoon population (1, 8). A similar case occurred when large numbers of racoons were translocated from Florida to West Virginia in 1977, again for hunting purposes. This particular relocation is still blamed for the subsequent epizootics of rabies in racoons and skunks in Pennsylvania, Virginia and Maryland (4), but after initial introduction, changing epizootiology of the disease can be attributed to other factors, e.g. racoon population increase correlates with reported increase in case incidence.

Sick specimens of the endangered Mojave desert tortoise (*Xerobates agassizii*), unwanted by their owners, have been released back into the desert and are believed to have infected wild tortoises with a fatal upper respiratory tract infection, probably acquired on pet shop premises (54).

Large numbers of hares (*Lepus europaeus*) imported from Hungary and Czechoslovakia into Switzerland and Italy for sporting purposes in the 1960s were infected with *Brucella suis*, a pathogen which can seriously affect domestic livestock (85). Plains bison (*Bison bison*), translocated in 1907 from Montana to Canada, brought with them tuberculosis (Box 1) and brucellosis; as a result, a decision was taken to slaughter 3,200 infected animals in an attempt to eliminate the diseases from the Wood Buffalo National Park in Canada, where they threatened the relict herd of wood bison (*B. bison athabascae*). However, public pressure caused the slaughter decision to be rescinded. Only recently has the situation been brought under control and at great cost (22).

## Diseases encountered by translocated animals at the release site

Animals born and bred on a distant continent in a very different epidemiological environment may have encountered diseases endemic in their area of origin (and may sometimes have become symptomless carriers of the pathogens), but they inevitably lack acquired immunity or resistance to the infections which will challenge them at the release site. Many diseases and parasites are highly localised in distribution as a result of the specific ecological requirements of the pathogens and the vectors; even translocation of wild-caught animals over short distances, from one eco-zone to another, can result in exposure to unsuspected disease problems. Some examples are given in Table II.

**Table II**
**Diseases encountered at release areas by translocated wildlife**

| Translocated species | Origin | Disease encountered | Release area | Source of pathogens | Ref. |
|---|---|---|---|---|---|
| Bongo (*Tragelaphus eurycerus isaaci*) | United States (c/b) | Babesiosis | Kenya | Local artiodactyls | 63 |
| Roan antelope (*Hippotragus equinus*) | Namibia (w/c) | Theileriosis | Swaziland | Tick vectors | |
| Sable antelope (*Hippotragus niger*) | | Babesiosis | South Africa | Tick vectors | 70 |
| Bighorn sheep (*Ovis canadensis*) and mule deer (*Odocoileus hemionus*) | United States (w/c) | Babesiosis | United States | Tick vectors | 102 |
| Bighorn sheep (*Ovis canadensis*) | United States (w/c) | Pasteurellosis | United States | Sheep | 37, 101, 102 |
| Eastern woodrats (*Neotoma floridana*) | United States (w/c) | *Baylisascaris procyonis* | New York | Racoons | 30 |
| Black rhino (*Diceros bicornis*) and white rhino (*Ceratotherium simum*) | South Africa, Kenya (w/c) | Babesiosis, theileriosis, trypanosomosis | Masai Mara, Tsavo, Meru, Kenya; Ngorongoro, Tanzania | Tick and tsetse vectors | 62, 69, 75 |
| Koala (*Phascolarctos cinereus*) | Victoria, Australia (w/c) | Tick paralysis (vector: *Ixodes* spp.) | Victoria, Australia | Toxic agent in the saliva | |
| Caribou (*Rangifer tarandus*) | Eastern United States and Quebec (w/c) | Cerebrospinal nematodosis | Ontario and Nova Scotia, Canada | White-tailed deer (*Odocoileus virginianus*) | 3 |
| Arabian oryx (*Oryx leucoryx*) | United States (c/b) | Botulism | Oman | Enzootic in Oman | 105 |
| Muskrat (*Ondatra zibethicus*) | Canada (w/c) | Tularemia | Soviet Union | Water voles (*Arvicola terrestris*) | 85 |
| Golden lion tamarin (*Leontopithecus rosalia*) | United States (c/b) | Unspecified | South-eastern Brazil | Not known | |
| Hawaiian goose (*Branta sandvicensis*) | United Kingdom (c/b) | Avian pox (vector: mosquitoes) | Hawaii | Local birds | 14, 59, 60, 86 |
| Brush-tailed possum (*Trichosurus vulpecula*) | Tasmania (w/c) | Bovine tuberculosis | New Zealand | Deer, wild pigs, etc. | 48 |

c/b: captive bred
w/c: wild caught

A number of inter- and intra-continental antelope translocations have resulted in mortality associated with exposure to local piroplasms. Bongo (*Tragelaphus eurycerus isaaci*) reintroduced into the Mount Kenya National Park from zoos in the United States in 2005 (63) suffered disease after exposure at the release pens and an undisclosed number died. Translocation of roan antelope (*Hippotragus equinus*) from the United Kingdom (UK) to Swaziland and of sable antelope (*Hippotragus niger*) from the UK into South Africa (70) has been constrained by difficulties in getting the animals to adapt to local conditions, and exposure to *Babesia, Theileria* and *Rickettsia* has been a problem.

Caribou (*Rangifer tarandus*) and moose (*Alces americana*) are seriously affected by the 'meningeal worm' (*Pneumostrongylus tenuis*) of white-tailed deer (*Odocoileus virginianus*), and attempts to translocate these ungulates into the white-tailed deer range in north-eastern areas of the United States have been frustrated by cerebrospinal nematodosis acquired by the accidental ingestion of infected terrestrial molluscs while grazing (3). Another neurological disease occurred in eastern woodrats (*Neotoma floridana*) as a result of infection with *Baylisascaris procyonis* (a neurotropic roundworm of racoons) following the reintroduction of woodrats in New York (30).

Exposure of translocated animals to a wide range of pathogens has led to recorded deaths and disease when released. Botulism is enzootic in sheep and goats in Oman, and Arabian oryx bred in captivity under zoo conditions in the United States died of this disease when they were released into the desert of Oman (105). Exposure of reintroduced black-footed ferret (*Mustela nigripes*) in the United States, an endangered species, nearly led to failure of the project and the extinction of these animals (116).

When muskrats (*Ondatra zibethicus*) were introduced into the former Soviet Union in the 1930s to augment the population of local fur-bearing rodents, they multiplied rapidly. At the time, tularemia was enzootic in local water voles (*Arvicola terristris*) which shared the wetlands with the translocated muskrats. Muskrats are highly susceptible to tularemia, and there ensued a massive epizootic of the disease in their expanding population. Tularemia is a zoonosis and it was not long before the disease affected muskrat trappers as well. In this case, a disease which, previous to the muskrat translocation and population explosion, had been enzootic in the water voles and sporadic in the human population, assumed epizootic proportions and became a serious health hazard to humans and wild animals alike (85).

In another, much-publicised translocation, captive-bred golden lion tamarins (*Leontopithecus rosalia*) were reintroduced into a protected area in south-eastern Brazil; in the first two years, 18 of 26 'acclimatised' animals died or were missing. The majority of deaths occurred shortly after release due to a variety of causes, of which 'disease' was said to be the main factor. After conjecture about herd immunity in captivity and in the wild, it was suggested that 'some kind of immunological preparation, possibly including vaccination against specific infections, may come to be a significant part of the reintroduction programmes' (21). Commenting on this reintroduction fiasco, Plowright (88) remarks that it is impossible to see how this type of immunological preparation could be achieved without identification and culture of the 'natural' pathogens and development of the associated serological techniques. He also noted that zoological collections provide a very unreliable guide to the diseases which may occur in the wild.

Failure of the Hawaiian goose (*Branta sandvicensis*) to increase in number after reintroduction may have been due to its occupancy of only the higher altitudes of its historical range. Breeding had formerly occurred at lower, more suitable altitudes, but these became infested with introduced mosquitoes, vectors of avian poxvirus to which the goose was susceptible (60).

Many years ago, brush-tailed possums (*Trichosurus vulpecula*) from Tasmania were introduced into New Zealand to establish a new species of fur-bearer. The animals found an empty ecological niche and multiplied greatly, in spite of heavy trapping for the fur trade. When the demand for possum collapsed, trapping ceased to be economically attractive. There are now over 70 million possums in New Zealand and 3% to 30% of them are said to be infected with bovine tuberculosis, a disease which does not occur naturally in possums in Tasmania (48). These translocates were exposed to dairy cattle and acquired infection which was maintained in the growing possum population. The economic consequences for the livestock industry in New Zealand, including deer farming, need hardly be stressed.

When translocated along with a wild animal host, avirulent, inapparent infection can sometimes become virulent on passage through a new host in a new environment. An example of this occurred when a number of wild rabbits (*Oryctolagus cuniculus*) were translocated from the UK to South Africa. A small number (5.7%) of rabbits in the UK carry an avirulent strain of toxoplasma. On reaching South Africa, these animals infected local rats (*Rattus natalensis*) and the passaged toxoplasma assumed a virulent form for humans (55). On the same theme, translocation into a new area can result in exposure to opportunistic bacterial pathogens subtly different from those present in the source population. Big horn sheep suffered mortalities from pasteurellosis after translocation and this occurred in a pattern consistent with transmission of the bacteria from in-contact healthy sheep (37, 101, 102).

# Minimising the risks

The success of translocation projects depends to a large extent on the ability of the scientific and technical team to evaluate the suitability of the release site chosen, and the ability of the translocated animals to colonise the area and establish a viable breeding population.

In this context, the veterinary dimensions of translocation projects are of great importance, and failure to carry out adequate preliminary investigations has already resulted in serious disease outbreaks. Worse still, the introduction of destructive parasites and disease agents into often naïve resident populations has had profound negative consequences. It is therefore important that systematic veterinary investigations be carried out prior to the choice of the release site so that all ecological risks can be assessed in advance and, if necessary and feasible, appropriate modifications made to the translocation plans. There are now some useful toolboxes to aid translocation planning which implementers are strongly advised to use (50).

## Veterinary intervention at the source of the release or among founder stock

Veterinary involvement should begin as early as possible in the preparation of translocation and release plans so that the risks can be identified and avoided.

The criteria for the selection of founders for a reintroduction attempt have been discussed by Stanley-Price (105). Reintroduction projects are usually high profile and planning usually extensive. This is not the case for all translocations and indeed, animals are not only translocated for reintroduction or conservation purposes. Rehabilitation of sick or 'rescued' wildlife often involves translocation and release. This has become a common, largely uncontrolled and unmonitored activity, with often little consideration of the potential disease risks. These 'rescued' wild animals are rarely in optimal health and sometimes rehabilitation is attempted, including release, without knowledge of chronic disease processes. Very often they are returned to locations far from their capture site. In most cases the animals are not adequately monitored after release. A case involving orangutans (*Pongo pygmaeus*) in Indonesia is worth describing. In this example the release of the apparently rehabilitated animals was cancelled due to the discovery of human tuberculosis in members of the group (10).

The approach to disease avoidance should start with an appropriate risk assessment and protocols developed accordingly from this basis. In cases of translocation other than wild to wild movements within the same ecosystem, the animal(s) should be placed in quarantine for a minimum of thirty days. The site of the quarantine station may be at the zoo, wild animal park, rehabilitation or breeding centre or ranch where the animals were raised, or it can be at a separate location if animals from a number of different sources are to be combined. The main requirement is that the group should be completely isolated from its own and related species, and if possible from all species, with the necessary exception of a limited number of human attendants.

In some instances and with some species there is criticism of this blanket condition, especially with delicate species and birds which do not easily adapt to the quarantine environment. The stress associated with this management can sometimes precipitate disease in an otherwise healthy animal. To explore the validity of this argument there have been attempts to scientifically evaluate the impact of quarantine. Saddlebacks (*Philesturnus carunculatus*) were reintroduced to Bushy Park Reserve in New Zealand in May and June 2006. The reintroduction is part of the restoration programme for Bushy Park, which was enclosed by a predator-proof fence in May 2005 and mammalian predators subsequently eradicated. Forty birds were sourced from Mokoia Island in Lake Rotorua and the plan for the release was to keep 10 birds under quarantine for two weeks and treat with toltrazuril (for coccidiosis) and iltraconazole (for aspergillosis), keep 10 birds under quarantine with no treatment, release 10 birds immediately with treatment, and release 10 birds immediately with no treatment. The aim of this experiment was to assess the impact of the quarantine and treatment procedures now being routinely enforced in reintroductions. However, the occurrence of *Plasmodium* (malaria) in four of the initial 20 birds meant quarantine was extended and all birds treated, and the birds were held more than one month before release. Two birds subsequently died in the holding aviary, and many others disappeared shortly after release, leaving a population of about 20 birds at the start of the breeding season in September. This illustrates the frustrations associated with the procedure, but also how important it remains to protect recipient populations from disease (71, 92, 94).

Usually the quarantine period and health screening requirement is defined by the veterinary import regulations of the receiving country. This will vary and with wildlife is often dealt with on a case-by-case basis. Serological or other diagnostic tests are frequently arbitrarily applied and certainly rarely validated for use in the target species. Governments usually err on the side of caution and even with non-specific tests will reject shipments on a positive result. Quite often the only tests required are those which satisfy human and livestock health regulations; tests for infections that might be of importance in the conspecific or sympatric species in the relocation area are not often required. This means that the quarantine procedures laid down in government import

regulations may not be sufficient to provide protection against these infections. This calls into question the reliability of the import procedures and places considerable onus on the risk assessment, because the result of this assessment becomes the most important factor in defining appropriate quarantine procedures. The quarantine premises must be appropriate for the species concerned and for the epidemiological situation, e.g. netted enclosures will need to be provided where arthropod-borne diseases are to be excluded. It is likely this was not the case in the saddleback example above. The premises must also facilitate visual and clinical examination, as well as sampling and chemical immobilisation, if necessary. Isolation from all possible sources of infection must be absolute and human attendants must be screened for transmissible diseases, e.g. tuberculosis. Early in the quarantine period disease screening procedures must be instituted, such as the following:

*a)* The breeding history and clinical records of the founder stock (if available) should be examined. Since the translocation group gathered at the quarantine station may have their origins in a wide variety of wild, semi-captive or captive environments, this may prove tedious. However, it is an important procedure because poorly managed captive animal facilities and populations frequently have a poor health status, especially for such diseases as tuberculosis, and this will influence the interpretation of subsequent tests.

*b)* The stock should be observed as closely as possible and the veterinarian should look for aberrant behavioural traits as well as clinical signs. When the animals are released and exposed to the selective forces of their new wild environments any physical or behavioural abnormality will reduce their chances of survival. This is particularly important when the founders are derived from captive-bred stock. Animals that have been hand-raised or accustomed to humans are only rarely suitable for release into natural ecosystems.

*c)* Local and regional disease patterns in the source area must be assessed, through international organisations (e.g. the World Organisation for Animal Health [OIE]) and national bodies (e.g. government departments of agriculture or livestock services) and principally, through the advice of local veterinarians, wildlife biologists and livestock farmers. On the basis of these enquiries and a knowledge of the common pathogens of the species to be translocated, the veterinarian should prepare a practical screening protocol which will also take into account any disease problems which may have been associated with previous translocations of the taxon, as well as any pathogens stipulated by international or national veterinary authorities as being of particular concern for the release country.

*d)* Before undertaking the screening procedures, all founder animals should be permanently marked by ear tag, tattoo and/or electronic micro-chip.

*e)* Biological samples should be sent to internationally recognised reference laboratories that have the requisite expertise and the appropriate tests to provide rapid and reliable results upon which to base decisions, and which will stand up to later scrutiny if required. It is often advantageous to send replicated samples to different laboratories in order to obtain independent verification of the results.

*f)* Laboratory procedures for the direct and indirect detection of evidence of infection should be based on a tier system.

## Laboratory detection procedures – tier one

The first tier can include:

– clinical haematology, including thick and thin blood smear for detection of haemoparasites (for trypanosomes the buffy coat of a micro-haematocrit tube filled with capillary blood may be examined)

– urinalysis

– biochemical analysis

– faecal and sputum culture for bacteria (and if appropriate virus detection)

– parasite egg and larval examination.

## Laboratory detection procedures – tier two

The second tier of testing will include specific tests for detecting the presence of diseases of concern to the authorities (e.g. screening requirements according to the regulations) and for disease processes suspected or identified from the history of the source locations or results of first-tier tests. These tests will involve antibody detection to determine that the group is free from a particular infection or disease. It is important to consider the likely prevalence of the disease in that population, should it be infected, and to take a sufficient statistically valid number of samples to detect at least one case with a given confidence. This varies according to the disease and species concerned and will not always be known. Positive antibody merely indicates exposure (or vaccination) and does not necessarily mean the animal or population is infected with the pathogen the test is designed to detect. Interpretation is critical, and to ensure confidence in any given result the test should be validated for the target species. This is ideal but in truth rarely are any tests validated for use in wildlife species. There are likely to be false positives and negatives when applying un-validated tests on wildlife samples and this needs to be carefully assessed in the particular case and risks of an error determined.

### Laboratory detection procedures – tier three

The third tier testing confirms if the animal(s) are infected with, or a carrier of, a particular pathogen. This involves antigen detection and a variety of test methods are available, e.g. enzyme-linked immunosorbent assay, molecular biological techniques, reverse transcriptase polymerase chain reaction, and immunohistochemistry. The same principle of sample size and predicted prevalence holds for this tier.

There are specific manuals and standard procedures for many tests (123). With this three-tiered approach, the main concern for project managers is the cost, which can be considerable, but its importance should not be underestimated. If instituted, it will encourage managers involved in the process of translocation to move only healthy populations rather than those that might just be easily available or cheap to purchase.

In some cases, a total ban on the importation of certain species (e.g. into a 'clean' country or marine environment) may be desirable. For example, Greenwood and Cooper (41) drew attention to the likely danger represented by prairie falcons (*Falco mexicanus*) and great horned owls (*Bubo virginianus*), both of which are commonly infected with falcon herpesvirus, and suggested that the importation of these species from the United States into the UK should be restricted or banned. More recently, the European Commission banned the importation of all captive wild birds into European Union countries in response to a risk assessment commissioned to look into the risks associated with this activity, including the risk of introducing highly pathogenic avian influenza virus (7).

## Veterinary intervention at the proposed release site

Where possible, the veterinarian should visit the proposed release site during the planning phase and risk assessment (and well in advance of translocation) to carry out the following tasks, modified where necessary for the species concerned:

– consult with the directors of the veterinary and wildlife services of the recipient country (this is important to avoid misunderstandings and to ascertain whether special tests or certification are required by these directorates)

– determine which diseases of wildlife and domestic animals and which vectors and reservoirs are enzootic in contiguous territories. A study of the wildlife–livestock–human interface, including local seasonal wildlife migrations and domestic livestock trade routes, is also relevant

– consult regional veterinary authorities with regard to the prevalence and incidence of local diseases

– consult the local diagnostic laboratory on the results of recent domestic animal disease surveys

– decide if the vaccination programmes of the national Veterinary Services can provide susceptible mammal wildlife with adequate protection against diseases such as rabies, anthrax, foot and mouth disease, peste des petits ruminants (PPR)

– examine the historical records of disease prevalence in the recipient site and population of animals, wild and domestic; where gaps exist or if there is a lack of baseline data, undertake appropriate surveys. It is usually unrealistic to undertake comprehensive surveys for all diseases at the release site and local knowledge is critical in the risk assessment

– investigate the availability of suitable vaccines to protect translocated animals against local disease hazards identified during these investigations

– determine whether any mineral or trace element deficiencies or excesses occur in the release area (if supplementary feeding is planned, foodstuffs – especially hay – may have to be transported over long distances from a different eco-zone and should be checked for toxic substances, e.g. selenium, and for ticks and other parasites)

– determine whether or not there are poisonous plants in the release area, which is highly likely, and to carry out a risk assessment on the likelihood of translocates coming into contact and eating them. If the risk is high an alternative release area should be identified. The probability of translocates eating poisonous plants is likely to be higher if there is an alien invasive plant species in the habitat concerned

– investigate why the species to be translocated is absent from the area. (Have previous translocations failed? Are the disease challenges high or are the ecological conditions now unsuitable for the survival of the species concerned?)

– prepare a report and send at least one copy to the directorates of the veterinary and wildlife services of the recipient country.

## Pre-release planning

The strategy of confining an integrated social group in a large, open enclosure near or in the release area for a considerable period before release has frequently been applied. This strategy has a number of advantages (105):

– social groupings can be adjusted and become established

– the period of confinement acts as an extended quarantine during which clinical signs of infectious or contagious disease may be detected

– contact with domestic stock and other wildlife can be excluded, thus reducing the chance of disease transmission

– translocates can become acclimatised to local conditions

– handling is minimised but can also be employed, when necessary, if the enclosure is equipped with a well-designed crush or restraint system.

Once the animals are released, there will be little chance of intervening to provide protection against the challenge of disease agents. Nevertheless, successful attempts have been made in a few unique circumstances with wildlife and are worth mentioning. Vaccination of the red fox (*Vulpes vulpes*) against rabies in Europe was a success, although it was expensive and depended on there being few competing scavengers for the oral bait (15), attempts using the same method elsewhere, e.g. eastern United States, have been less successful. Trials on vaccinating Ethiopian wolves (*Canis simensis*) and wild dogs (*Lycaon pictus*) are ongoing and this measure would probably be useful in the face of an outbreak and in small isolated populations, but impractical and relatively ineffective as a prophylactic measure across large landscapes. Vaccination can be used in exceptional circumstances, of which reintroductions are one example, but its continued or repeated application after release will depend on the circumstances and in most instances will be unsustainable. Once the population is large enough to show resilience in the face of an epidemic vaccination is probably no longer required, as natural epidemiological processes will achieve the same result. There was an attempt to routinely vaccinate roan antelope (*Hippotragus equinus*) against anthrax (32) in the Kruger National Park in South Africa, because the population was small and vulnerable. The vaccination programme had some success but has largely been discontinued, as the decline in antelope numbers continued irrespective of this practice. It is recommended that vaccination of endangered species be considered in the face of an anthrax outbreak (110) and probably the first effective attempt at this was undertaken in Kenya when the small surviving population of some thousand or more Grevy's zebra was exposed (72).

## Interpretation of survey and screening results

Investigating the disease history of the source of the animals will help in deciding if any biological tests should be given priority. Information that source populations have been vaccinated against a certain disease (e.g. leptospirosis) may suggest that this disease is a problem. Tuberculin tests for animals originating from populations where tuberculosis is enzootic (few will admit this) need to be interpreted more carefully than where the disease is unknown in the population. A number of diseases produce antibodies which cross-react in different laboratory tests and this must be taken into account when interpreting results, e.g. bluetongue and epizootic haemorrhagic disease; rinderpest and PPR (64). Single sample data is generally unreliable and sample size is important when examining the source population to confirm the presence or absence of any disease. Further testing, e.g. virus isolation can be employed if positive antibody test results are obtained. Zebra and wild African suids are symptomless carriers of African horse sickness and African swine fever viruses respectively, and African buffalo are reservoirs of SAT-type foot and mouth disease (FMD) (46) and these animals are therefore subject to strict international movement regulations. Aardvarks (*Orycteropus afer*) may have antibodies to FMD and elephants (*Loxodonta africana*) may have antibodies to African horse sickness or African swine fever, but the significance of these antibodies is unclear, which serves to illustrate the difficulties (Fig. 1). With birds, which are frequent carriers of avian influenza and Newcastle disease viruses and of bacteria such as *Salmonella* and *Campylobacter* spp., decisions on translocation become even more challenging, as the diseases caused by these pathogens are often symptomless and one-off screening can miss a high proportion of infected individuals (17, 58, 74). When considering introducing disease-screening protocols, overall risk assessment will help in deciding on what intensity of investigation (i.e. individual screening or group testing) is required and reasonable. For example, a short-distance wild-to-wild translocation will not require as much screening as a zoo-to-wild translocation across borders, which carries a high risk of pathogen introduction. Different species will each need their own protocol as a 'one-size-fits-all' approach will not work.

There is evidence of growing interest in the translocation of small and diverse species, with the main increase in activity in the amphibian, insect and bird orders. Translocations of these species will require specialist disease knowledge which most practising veterinarians do not possess. Wherever it comes from, specialist advice will almost certainly be required for the interpretation of results of the investigations carried out both at the source and at the release site. International disease monitoring organisations such as the OIE, Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization may all be consulted, as may the Wildlife Health Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature (IUCN) and the Veterinary Services of the countries concerned.

**Fig. 1**
**African elephant (*Loxodonta africana*), Tsavo National Park, Kenya**
The translocation of the African elephant is technically difficult, but with appropriate equipment and trained staff it is a valuable tool in management. Despite considerable physical manipulation family groups which were moved are shown behaving normally after release. Disease risks from translocation are not well researched in this species and for international movements, which are rare, health regulations should be strict
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# Prophylactic vaccination of founder stock

The decision to vaccinate and the choice of vaccines will depend on the interpretation of the results of the surveys and investigations described above. For a review of the current knowledge on wildlife vaccination and the likely future use of vaccines see Plumb *et al.* (90).

Vaccination of released animals might have a short-term benefit but eventually the species will have to survive without this prophylaxis. The justification for vaccination is based on the risk of losing the investment in animals in the short term. There is some comfort in knowing there are only one or two examples of species extinction where disease is purported to be definitively the primary cause (Polynesian tree snail *Partula affinis* and sharp-snouted day frog *Taudactylus acutirostris* [100]).

Two main types of vaccine are available: modified live vaccines which have reduced virulence for one or more species, and inactivated vaccines which contain no viable organisms. The advantage of live vaccines is that they grow in the host after inoculation and usually induce a solid immunity similar to that found in animals which have recovered from natural infection with the pathogen (if such immunity occurs). Consequently, vaccination with a live vaccine usually requires only one inoculation, which is a great advantage when dealing with wildlife, especially those animals which need restraint. However, while live vaccines have reduced virulence for some species they may be pathogenic for others. For instance, live canine distemper virus (CDV) vaccines have induced disease in susceptible mustelids, including the endangered black-footed ferret (*Mustela nigripes*) (116). Similarly, live feline parvovirus vaccine (feline enteritis or panleukopaenia) which is innocuous for domestic cats is thought to have caused disease in other felines. Although safe in most breeds of cattle, a live rinderpest vaccine prepared in rabbits caused significant mortality when tested in a variety of African artiodactylids (19). Fortunately, the current cell-culture-derived rinderpest vaccine has proven both safe and efficacious in the wild species tested to date (13, 89, 88), but in only one case has it been used for prophylactic purposes in wildlife species. Translocated, critically endangered (IUCN Red List), hirola antelope (*Beatragus hunteri*) were vaccinated with the standard cattle vaccine for rinderpest, in Kenya, in 1996, and this was undertaken during an ongoing epizootic in the region. Vaccination was not associated with any mortality or ill health and no disease was reported in the introduced population despite known circulation of virus in the area in 1998. It is not known if the animals were challenged with virus, but the absence of disease reports in this susceptible species suggests it might have been beneficial. Rinderpest vaccination provides lifelong immunity with a single dose, which makes it an ideal product, and the increasing evidence for eradication of the disease globally is proof of this (64).

The control of rabies in Western Europe has been highly successful as a result of improved oral baits technology using live vaccines and sufficient coverage. A risk of the application was the uptake of vaccine in non-target species in which the vaccine might have proven virulent, but no evidence for this was reported, other than a single case of

human infection from a bite from a dog which had inadvertently picked up rabies vaccine bait in the United States (97). The success in Europe was no doubt due to the low species diversity, as its use elsewhere has had more equivocal results, except amongst localised fox populations (15). The use of modified live virus vaccination in the face of an outbreak of rabies was successfully applied with the Ethiopian wolf and its efficacy suggests that any translocated wolves should be vaccinated as a routine. This will, however, only convey immunity for a limited period to these individuals and have some value for their offspring whilst maternal immunity persists (66).

Although distemper is, on occasions, a devastating disease there is a strong immune response and survivors develop protective antibodies and remain immune for a considerable period. Wildlife populations are clearly able to survive in areas of endemic distemper without recourse to vaccination, whether in the face of an outbreak or prophylactically. Where there is a high population of infected domestic dogs living in close proximity to endangered carnivore populations, control of the disease is perhaps warranted, but studies of wild dog show a high prevalence of CDV (60%) in apparently stable wild dog populations (R. Woodroffe, personal communication, 2008). As in the case of rinderpest, there is no harm in vaccinating translocated carnivores or other mammals, but live virus vaccines should only be used when proven to be efficacious and safe in the species concerned.

For vaccination of translocates, live vaccines offer several advantages, provided they have been proven to be safe in the chosen species. Care should be taken to use a vaccine strain that has been successfully tested in the species, since different manufacturers may use different strains. Unless they have been tested with the vaccine, it is best to avoid vaccinating pregnant dams, as some live (especially viral) vaccines can cause foetal death and/or abortion. Similarly, some live vaccines may cause disease in very young animals, and the instructions of the manufacturer should be sought on this matter. If dams have been vaccinated previously, maternal immunity may reduce the immunogenicity of live vaccines administered to young animals (carnivores less than three to four months old, herbivores less than six months old).

Inactivated vaccines carry little risk of infecting the host, although some toxoids and adjuvants, which help to stimulate the immune response, may induce local reactions at the site of inoculation. However, since they do not replicate in the host, inactivated vaccines may require more than one application in the first instance, as well as frequent boosting. It remains to be seen whether this will prove to be the case with the inactivated CDV vaccine currently being investigated for the protection of harbour seals (*Phoca vitulina*) against phocine distemper (112).

A good example of the use of inactivated viral vaccine to protect a captive-bred species prior to exposure to infection in the wild is afforded by the case of the whooping crane (*Grus americana*). Although never abundant in North America, the whooping crane became endangered, largely because of habitat modification and destruction. To promote recovery, a captive propagation and reintroduction programme was initiated in 1966 at the Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland. However, in 1984, seven of thirty-nine whooping cranes at the PWRC died as a result of infection with eastern equine encephalitis (EEE) virus, an arbovirus which infects a wide variety of indigenous species, although mortality is generally restricted to introduced birds (23). Following identification of the causal agent, surveillance and control measures were implemented, including serological monitoring of both wild and captive birds for antibody, and examination of locally trapped mosquitoes. In addition, an inactivated EEE vaccine, developed for use in humans, was evaluated in the captive whooping cranes. Results suggest that the vaccine will afford protection to susceptible birds (81).

Vaccine solutions in wildlife are still the exception, often because there is inadequate financial support to carry out the necessary research and development where there is only limited or no commercial application. This is illustrated by the history of brucellosis in Yellowstone National Park. Here, North American plains bison (*Bison bison*) were infected with brucellosis (*Brucella abortus*) from transmission by livestock early in the 20th Century. Later, Rocky Mountain elk (*Cervus elaphus*) living around the park also acquired the disease. The risk of 'spillback' transmission of brucellosis from wildlife to livestock across the Greater Yellowstone Area caused concerns that led to extremely divisive legal and policy conflicts. Remote brucellosis vaccination of the Yellowstone bison population is increasingly being viewed as a component of adaptive risk management strategies which aim to eventually eliminate the disease. However, novel vaccines will need to be developed because the extant bovine brucellosis vaccines S19 and RB51 have not proven very effective in reducing shedding of *B. abortus* into the environment or limiting maternal or foetal infection in bison or elk (90).

In general, if the risk is considered high for a particular infection and vaccines are available, it is advisable to employ an inactivated vaccine, if available. Failing this, a live vaccine could be tried in one or two animals, provided these are isolated from the rest of the group.

Protective immunity may take a few days or several weeks to develop. Immunisation should therefore be carried out well in advance of translocation (this provides a further quarantine period in case the animals are incubating a field

infection or excreting the live vaccine agent administered to them). For some vaccines there is no guarantee that the vaccine virus will not revert to a virulent form and this should be taken into consideration with each vaccine; it should also be remembered that some live vaccines induce persistent infections, vaccinates in effect becoming carrier animals which may pass on infections to vectors or susceptible species. For example, in humans, poliomyelitis vaccination via live oral polio vaccine (OPV) suffers from the inherent problem of reversion: the vaccine may, upon replication in the human gut, mutate back into a virulent and transmissible form, resulting in circulating vaccine-derived polio viruses (113). Fortunately such cases are rare. Translocation practitioners also need to bear in mind that if the animals are moving to a new country the livestock authorities there may not want animals to have certain antibodies. Therefore any vaccines used in the translocates must have the approval of the importing authorities.

# Post-release health monitoring

Regular, systematic monitoring of the health and reproductive performance of translocated animals may provide an early warning of incipient disease problems. If the cause of disease or reduced productivity can be determined, a change in management may be indicated for current or future translocations.

Provision for long-term monitoring is often included in translocation project plans but is rarely carried out once the released animals appear to be surviving in the wild. Post-release monitoring of the Hawaiian goose was recommended during the project design (60), although little monitoring actually took place. After the release of 1,244 birds over sixteen years on Hawaii and a further 391 on Maui Island, the status of the reintroduced population was unknown and the reasons for the limited success (believed to be associated with avian poxvirus infection, but this has not been proven) were a matter for conjecture (14).

# Future problems

Veterinarians concerned with wildlife translocation should also be aware of emerging or potentially emerging disease problems, including:

*a*) Peste des petits ruminants. This rinderpest-like disease of sheep and goats is distributed across Asia, West, Central and East Africa. It has recently been confirmed as the cause of mortality in free-ranging ibex in Sindh Province, Pakistan (G. Qadir Shah, personal communication, 2009) and it has caused fatal disease in captives (38). The disease is currently extending its range eastward in Asia and southward in domestic stock in Uganda, Kenya and Tanzania. There is antibody evidence that a range of wildlife species in East, West and Central Africa are now infected (62, 64). Peste des petits ruminants is a disease of growing importance which will have to be considered in any plans for moving wild animals into, out of, or within the Asian and African regions.

*b*) New World screwworm (*Cochliomyia hominovorax*). This disease was accidentally introduced into Libya and Central America in 1988, showing the ease with which a devastating parasite can be transferred from one hemisphere to another, in this case by domestic stock. The cost of the successful eradication programme carried out by the FAO was in excess of US$80 million.

*c*) Rinderpest. Progress in the eradication of rinderpest from Africa and the world is significant, with no evidence of the lineage 2 strain of virus that was isolated in the 1990s and had been circulating in wildlife until 2001 (64). The virus is cryptic in livestock and there needs to be intense serological and clinical surveillance until sufficient time has passed to be sure of its disappearance (73). Vaccination has stopped globally, which it is hoped will bring out the infection should it still remain in any population.

*d*) Tuberculosis caused by *Mycobacterium bovis*. This disease is present in many captive and wild animal populations (11). In some populations it appears to be of minimal significance, for example, the 10% antibody prevalence in wildebeest in the Serengeti ecosystem in Tanzania (27) is not associated with visible disease or decline. However, in other populations, the infection is currently of considerable concern, for example, in the Kruger National Park in South Africa the disease is epizootic and significantly impacting multiple species. Several studies have provided valuable insights into the presence of tuberculosis in wildlife populations (25, 31, 120, 121) and repeat sampling has shown that at least one species, the African buffalo, can be a maintenance host (56). The explanations for this apparently different epidemiology are not entirely clear, although higher animal density and use of artificial water points might be key factors (31). Other wildlife infections have been of considerable concern to livestock industries in the UK (107) and New Zealand (48). Despite huge investment in control tuberculosis remains emergent, but in the affected wild species, the ecology and population viability remain apparently unaffected by the disease.

*e*) Brucellosis. This disease, an economically important disease in wildlife in North America and prevalent in Africa

and Asia, is self-limiting in wild ungulates but is perceived as a constant threat to contiguous domestic livestock. Vaccination challenges in wildlife remain for this disease as described above.

*f)* Sarcoptic mange. This is a ubiquitous, serious and recurrent disease, sometimes of epizootic proportions, affecting a wide range of wildlife species: gorilla (*Gorilla gorilla berengei*), cheetah (*Acinonyx jubatus*), Spanish ibex (*Capra ibex*), Swiss chamois (*Rupicapra rupicapra*), Swedish foxes and Pakistani blue sheep (*Pseudovis nayaur*) (57, 76, Woodford, personal observation, 2007).

*g)* Malignant catarrhal fever (MCF). This disease is a killer of rare deer species, such as Père David's deer (*Elaphurus davidianus*) and also presents a serious threat to endangered Asian wild cattle (78) and to ranched bison (68). The last ten to fifteen years have shown that the susceptibility of bison to sheep-derived MCF probably equals or exceeds that of cattle to wildebeest-derived MCF and that transmission can occur over considerable distances. The possibility of the spread of MCF infection to these species by carrier wildebeest (*Connochaetes taurinus*) or domestic sheep should be remembered.

*h)* Foot and mouth disease. This is of major economic significance in some African countries, particularly those exporting beef to Europe, such as Botswana and South Africa. Although large areas of these countries have been declared free of FMD, other areas (usually inhabited by herds of buffalo) may be enzootic for FMD. The intentional translocation of wild ungulates from affected to FMD-free zones is likely to be permitted (if at all) only after stringent testing and prolonged quarantine.

*i)* H5N1. The first confirmed case of infection in Europe in domestic animals was in a cat found dead on the coast of the Baltic Sea off the Island of Rügen, North Germany in February 2006. Subsequently, two more affected stray cats and one stone marten (*Martes foina*) have been reported from this area. All affected mammals were found in an area with a high incidence of H5N1 infection in wild birds, and where they had access to the carcasses of dead, infected wild birds (98). The translocation and release of raptors during hunting activities in both Europe and the Near and Far East (and the feeding of these birds with chicken heads) is exposing birds and their prey to infectious agents such as highly pathogenic avian influenza virus H5N1. This seasonal recreation is increasing the risk of local spread at the hunting sites and infected falcons could return to their captive locations and create further spill-over opportunities. Similarly, wild birds captured and sold through the trade in exotic companion animals have proven to be a source of H5N1 virus and are considered a risk (7).

# Cryopreserved germplasm: the risk of disease transmission

Although there has been some progress in the science of assisted reproduction in wild species through the use of frozen semen, ova and embryos (2, 99), the techniques, despite decades of optimism, are rarely implemented. Their use is mainly confined to zoological collections, with one or two attempts at assisted reproduction in semi-captive animals as part of reintroduction or reinforcement programmes. If the constraints (high cost and low efficacy) of this approach for wildlife species are reduced, genetic resource banking programmes might become established and the disease implications of these activities will have to be addressed. Extrapolating from domestic livestock, where these methods are widespread and routine, the disease transfer risks are minimal, because embryos inherently carry a lower risk of transmitting viral and bacterial disease agents (e.g. FMD and bovine leukaemia virus) and semen can be more easily stored and tested for sterility than can live animals. The diseases transmissible by semen and embryo transfer have been reviewed by Hare (45) and Singh (103). If appropriate female animals could be obtained from wild recipient populations and their health maintained in captivity, they could be used as surrogate mothers in which to translocate germplasm. A useful bonus could be the natural transfer of local immunity to the foreign embryo through trans-placental and colostral routes, thereby improving the chances of survival of the offspring. Given the low risk of embryos transferring pathogens, the restrictions currently in place based on dam status, might even be unnecessarily restrictive. The example of removing neonates from infected mothers to achieve TB and FMD disease-free stock in Saudi Arabia and South Africa, with oryx and buffalo respectively, are illustrations of the value of this approach where disease in parent stock is a concern (45).

# Discussion

Whatever the purpose of translocation, conservation or trade, there is always a significant risk that disease will be transmitted and vectors or pathogens will be transferred within translocated groups or to recipient populations. This risk needs to be assessed in all cases. Perhaps the most underestimated threat is humanity itself. Humans are now the most abundant and dominant of all mammal species and they move, with little or no health restrictions, throughout the globe daily. The increased incidence of human-origin tuberculosis in wildlife species is perhaps an example of this increasing exposure of animals to a diversity of human pathogens.

A considerable number of species have been reintroduced into the wild after captive propagation but, by the strict interpretation of the word, few of the populations can be considered to have been truly re-established as yet or viable for the longer term. In a number of cases – Père David's deer, Przewalski's horse (*Equus przewalskii*), red wolf (*Canis rufus*), Arabian oryx, Guam kingfisher (*Halycon cinnamomina*), California condor (*Gymnogyps californianus*), black footed-ferret, and Guam rail (*Rallus owstoni*) – the species were extinct in the wild at the time of the reintroductions: Père David's deer, in fact, had been extinct for 800 years!

In early projects, no systematic attempts were made to quantify and minimise the veterinary risks attending the translocation of the founder animals. More recently the practice has improved: risk assessments have been undertaken and there have been careful screening and preparation of animals for translocation and reintroduction, e.g. black-footed ferret, Arabian oryx, sand gazelles (*Gazella subgutturosa marica*), mountain gazelles (*Gazella gazella*) and red kite (*Milvus milvus*). In these cases the secret to success has been the captive breeding projects established in the country of release with long-term monitoring and management programmes. Other, expensive, multiple-source reintroductions from zoos, sometimes imposed on recipient countries without sufficient planning or local involvement, have been expensive failures or at best only partially successful. However, most problems that arise when animals are reintroduced occur not because translocated animals introduce disease, but because these naïve, poorly adapted, captive-bred animals become infected when exposed to local pathogens or contaminants (63, 82, 119).

The 'rescue', rehabilitation and release of wild animals are highly risky and there is little evidence to justify these activities, either from an ethical or an ecological perspective. Many released animals will die and wild populations will not benefit from this practice, but are more likely to suffer problems such as disturbance, territorial aggression, genetic pollution and introductions of disease. Despite scientific evidence to discourage this activity it is widely practised and receives the attention and financial support of the general public. When considering any such reintroduction of wild animals, it is worth bearing in mind expert advice regarding the likely impacts of species on recipient populations and potential for success; for example, carnivores are generally poor candidates for reintroduction despite being amongst the most popular animals for this activity. They are large, aggressive species and when placed within wild populations, with established territories, are highly disruptive and are killed or kill others. At best they are displaced tens of kilometres away from the release site and often become problem animals in human landscapes, from where they were often originally rescued. Given the largely amateur nature of rehabilitation, scientific evidence and advice are unlikely to be heeded and this practice will probably require legislation and strict regulation in future.

**Fig. 2**
**Black rhinoceros (*Diceros bicornis michaeli*) introduced into Nakuru National Park and Tsavo National Park**
Note ear notching for identification purposes post-release and boma structure (enclosure), part of the release processing
© Richard Kock

**Fig. 3**
**White rhinoceros (*Ceratotherium simum*), Nakuru, Kenya from stock introduced from South Africa in the 1970s**
The white rhinoceros is often moved from one African country to another as part of introduction programmes. This species is not indigenous to Kenya but proves valuable for tourism in highly visited parks where the more cryptic black rhino are rarely visible
© Raj Amin

Members of the veterinary profession with experience and expertise in wildlife disease should become involved in risk assessment and implementation of translocation projects to ensure that appropriate quarantine and screening measures are in place. In special cases, the quarantine period may need to be extended (e.g. if

tuberculosis is perceived as a particular hazard [Box 1]). Given that there is such a variety of disease conditions and such a great range of taxa which may become the object of future translocation projects, no one set of guidelines can cover all eventualities. Each case must be separately evaluated, taking into account all biological, ecological, geographical and epidemiological circumstances. Only then will the inherent risks in moving potential 'disease packages' across the world be minimised and the chances of failing to establish a healthy new wild population be significantly reduced.

In the long term, the establishment of a database on infectious agents and diseases of wildlife will be a very important support activity. This has now been widely acknowledged given that a large majority of infectious disease agents are transmitted across multiple species and a high proportion of human and livestock diseases have wild animal origins. The establishment of the ISIS database (International Species Inventory System) to support captive wild animal collections is providing a basis for this approach and will at least provide some information, easily accessible, for some source animals, but as modern reintroduction science is showing, success rates are higher with wild-to-wild translocations for reintroduction, where wild populations still exist. With extinct in the wild, there is no choice. The publication of bulletins of wildlife disease occurrence on a global scale, drawing on information from databases, would assist veterinarians in evaluating the disease risks which may attend a translocation proposal. The search capacity and power of the internet will also help practitioners identify both established protocols and risks more easily. A general guideline has been written for reintroductions (51) and detailed translocation guidelines have been written for certain species (e.g. for elephants and rhinoceros) (52, 53) with comprehensive advice on all aspects, including disease (Figs 2 & 3). It is likely these will become more common in the future for hopefully the whole range of translocated species, thus providing a valuable resource for translocation practitioners.

■

# Risques sanitaires associés aux transferts de faune sauvage

R.A. Kock, M.H. Woodford & P.B. Rossiter

**Résumé**

Le transfert désigne l'opération consistant à déplacer des organismes vivants d'une région à l'autre en les relâchant dans la nature afin qu'ils fondent de nouvelles populations dans le site de destination. Chaque année, un nombre croissant d'animaux fait l'objet de ces transferts dans le monde. Généralement conduits par des agences privées ou nationales de protection de la faune, ces transferts portent, dans la plupart des cas, sur des espèces autochtones de mammifères, d'oiseaux et de poissons dont les populations existantes doivent être augmentées, habituellement à des fins de loisir. Le transfert d'espèces menacées d'extinction est également devenu une technique importante de préservation de la faune, au moyen de laquelle ces espèces sont réintroduites dans les segments de leur aire de distribution historique d'où elles s'étaient éteintes. Depuis une dizaine d'années, les projets de réintroduction se développent surtout dans le domaine des petits animaux, notamment les batraciens, les insectes et les reptiles.

Les projets de transfert peuvent être coûteux et ambitieux ; leur réussite dépend, dans une large mesure, du soin mis par les biologistes de la faune sauvage et par leurs conseillers vétérinaires à évaluer et à choisir de manière appropriée les animaux et le site de lâchage, ainsi que de l'aptitude des animaux transférés à coloniser ce site.

Les aspects vétérinaires des projets de réintroduction revêtent une extrême importance. Les auteurs rapportent plusieurs exemples où une évaluation

défectueuse des risques sanitaires a entraîné de coûteux échecs et, pire encore, a laissé libre cours à l'introduction d'agents pathogènes dangereux au sein de populations locales d'espèces sauvages naïves.
Un certain nombre de risques sanitaires à prendre en compte lors des transferts de faune sauvage sont également décrits. La conduite d'une évaluation du risque portant sur les populations fondatrices et de destination, ainsi que sur leur habitat respectif est désormais une condition préalable à ces transferts d'animaux.

**Mots-clés**
Faune sauvage – Préservation – Quarantaine – Réintroduction – Risque sanitaire – Transfert – Vaccination.

# Riesgos sanitarios ligados a la traslocación de animales salvajes

R.A. Kock, M.H. Woodford & P.B. Rossiter

**Resumen**
La traslocación se define como el desplazamiento, por obra del hombre, de organismos vivos de una zona con el fin de liberarlos en otra. Cada año hay un número creciente de animales que son objeto de traslocación en el mundo. La mayoría de esos movimientos afectan a mamíferos, aves y peces autóctonos y son obra de entes privados u organismos públicos de gestión de la fauna salvaje que buscan acrecentar las poblaciones existentes, en general con fines deportivos. Uno de los métodos importantes de conservación de la naturaleza que se ha venido practicando es la traslocación de especies amenazadas, a menudo para reintroducirlas en una parte de su área de distribución histórica de la que han sido extirpadas. En el último decenio ha aumentado el número de proyectos de reintroducción, que en su mayoría afectan a animales de pequeño tamaño, en particular anfibios, insectos y reptiles.
El éxito de proyectos de traslocación de animales salvajes más ambiciosos y potencialmente muy onerosos, depende en gran medida del detenimiento con que los biólogos y sus asesores veterinarios evalúen la idoneidad de los animales y del lugar de liberación elegido, y también de la capacidad de los propios animales trasladados para colonizar la zona en cuestión.
En todo proyecto de reintroducción los aspectos veterinarios revisten suma importancia. Hay casos en que no se valoran debidamente los riesgos, y ello provoca onerosos fracasos y, lo que es aún peor, la introducción de patógenos destructivos en poblaciones salvajes que se encuentran inermes ante ellos.
Los autores exponen algunos de los riesgos sanitarios inherentes a la traslocación de animales salvajes. La determinación del riesgo, que supone el estudio de las poblaciones fundadora y receptora y de sus hábitats respectivos, constituye ahora un requisito previo indispensable para el desplazamiento ordenado de animales.

**Palabras clave**
Animales salvajes – Cuarentena – Protección de la naturaleza – Reintroducción – Riesgos sanitarios – Traslocación – Vacunación.

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