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Asian Biotechnology and Development Review
Vol. 8 No.1, pp 45-76

Printed in India.

Potential Impact of Biological Weapons on Biological Diversity and Indigenous Peoples in Asia

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Abstract: Outbreaks of bioweapon diseases could result in the erosion of genetic diversity in domesticated plants and animals, the destruction of traditional human livelihoods, the extirpation of indigenous peoples, and the extinction of endangered wildlife species.

If not properly contained and monitored, the extensive research and testing programmes undertaken by the former Soviet Union for the development and weaponization of animal and plant pathogens for potential use as biological weapons could potentially represent a long-term threat to human populations, agricultural production, and biological diversity in Asia. Reports of atypical zoonotic diseases in Kazakhistan and Uzbekistan and other areas of Central Asia should be monitored closely as they could provide indications of potential residual contamination (or the escape and establishment in the wild) of weaponized or genetically-modified bioweapon disease pathogens.

Introduction

Our human capacity for modulating and altering basic ecosystem functions has now reached unprecedented levels, with evident global-scale human impacts on atmospheric composition, bio-geochemical cycles, and climates. Human agriculture and urbanization have resulted in radical restructurings and simplifications of regional landscapes, accompanied by major changes in watershed drainage and infiltration regimes and alterations in surface water and groundwater availability, flow regimes, recharge rates, and water quality parameters (e.g., pH,

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The authors thank Bruce Wilcox, Gary Hartshorn, and anonymous reviewers for comments on previous drafts of this manuscript.
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mineral and trace element content, nutrient loads, chemical contaminants). Human activities homogenize and degrade regional biotas through replacement or displacement of native biodiversity by cosmopolitan anthropophilic species of plants and animals (domesticated, commensal, and invasive species), and the subsidiary impacts of competition, predation, and disease infection on native species populations.

These and other human impacts on important fundamental determinants of ecosystem characteristics and dynamics have radically altered the natural ecology of disease pathogens and disease vectors in many areas of the world,[1] eliminating endemic diseases from large areas in which they were formerly prevalent while also creating epidemic disease problems in areas previously outside the natural, historical range of pathogens. The once-celebrated human conquest of infectious diseases through sanitation, antibiotics and vaccination has now faltered and may even be failing.[2] Diseases like tuberculosis, malaria and poliomyelitis that were once thought to be subject to total global eradication are now reclaiming lost ground with a vengeance, persisting and even spreading despite concerted international efforts at control and eradication. Insect and arthropod vectors of human and animal diseases are exhibiting resistance to commonly used pesticides, while improper and inappropriate uses of antibiotics to suppress diseases and infections in both humans and animals are contributing to the evolution through human selection of drug-resistant strains of many important bacterial diseases (e.g., tuberculosis, campylobacteriosis, and streptococcal and salmonella infections). Modern, high-speed air and surface transportation systems are generating sustained global pandemics of diseases like cholera that were once relatively localized within endemic areas, and exhibited only sporadic short-term outbreaks in conjunction with dispersal or introduction into new regions.[3] Smallpox (*Variola major*), extirpated from human populations throughout the globe during the 1970s following a decade-long intensive international eradication effort, has been maintained in laboratory cultures in bioweapons arsenals and may re-emerge as a global disease threat if released deliberately or accidentally into the environment.[4]

Around the world, many formerly obscure or unknown disease pathogens — particularly viruses — are now causing serious epidemics within and among populations of humans and animals, and many of these newly-emerging disease threats appear to be direct by-products of

the human alteration of ecosystems and regional landscapes.[5] Asia is the origin for several important newly-emerged fatal infectious human diseases transmitted between and among people, wildlife, and domesticated animals: the SARS coronovirus, Nipah virus, and H5N1 avian influenza. The increasingly widespread veterinary usage of antibiotics and antivirals used for the treatment of human diseases is creating highly dangerous drug-resistant strains of zoonotic disease pathogens, as shown by revelations which surfaced in June 2005 regarding the apparent widespread use of the human antiviral drugs amantadine and oseltamivir by farmers to prevent or treat H5N1 bird flu infections in poultry and the discovery that the H5N1 virus circulating in Vietnam and China exhibits amantadine-resistant properties. Habitat fragmentation and global tourism are contributing to the emergence of human diseases like polio and measles as potentially serious threats to endangered great apes in the tropical Africa and Asia,[6] in much the same way that habitat fragmentation and commerce have fostered the emergence of formerly unknown zoonotic diseases such as monkeypox, Nipah, Marburg, and Ebola as threats to human populations inhabiting these same tropical rainforest ecosystems.

There is also growing recognition of the emerging global threats to human and ecosystem health presented by disease pathogens that have been selected and cultured specifically for use as biological weapons.[7] Disease pathogens are now ranked by many analysts as the most dangerous of all modern weapons-of-mass-destruction technologies, with the potential for producing more extensive and devastating effects on human populations than chemical or nuclear weapons systems.[8] Zoonotic and epizootic disease pathogens known to have been cultivated and tested in bioweapon research programmes during the twentieth century included *Bacillus anthracis* (anthrax), *Yersinia pestis* (plague), *Brucella abortus* (brucellosis), *Apthovirus* (FMD), *Burkholderia mallei* (glanders), morbilliviruses (measles, canine distemper, rinderpest), *Staphylococcus*, *Francisella tularensis* (tularemia), rabies, Venezuelan equine encephalomyelitis virus, and several virulent hemorrhagic fever viruses (Ebola, Marburg, Lassa fever, Rift Valley fever). Pathogens cultured and tested for bioweapons applications against agricultural crops include a large number of fungal diseases and plant viruses. Fungal diseases of plants originally developed for attacks against food crops (e.g., *Fusarium* spp.) are now being tested for use against illicit drug crops (opium poppies, coca plants, marijuana). Once

introduced into new environments, plant bioweapon diseases could potentially infect non-target species of wild and cultivated plants and become permanently established.[9]

Infectious diseases and plant toxins have been used as weapons of war since time immemorial.[10] Biological weapons are now globally distributed, and at least 22 countries around the globe are widely believed to have had – operational bioweapons research programmes at some time during the past two decades (e.g., Algeria, Bulgaria, China, Egypt, France, Germany, India, Iraq, Iran, Israel, Japan, Libya, Netherlands, North Korea, Norway, Pakistan, Romania, South Africa, Sweden, Syria, Taiwan, U.S.S.R. [Russia, Kazakhstan], United Kingdom, and the United States).[11] Prior to its political dissolution, the former U.S.S.R. created the most extensive and sophisticated biological weapons (bioweapons) research and development industry on earth. The USSR bioweapons programmes included parallel and independent military and civilian BW R&D infrastructures that did extensive work on agricultural pathogens and pests (plant and animal diseases, insect and arthropod disease vectors) as well as human disease pathogens, and reportedly created genetically engineered strains of smallpox, tularemia, glanders, anthrax, and plague.[12] The former U.S.S.R. supported extensive military and civilian research programmes that tested possible bioweapons applications of a fungal diseases of food crops (e.g., wheat stem rust, rice blast), viral and bacterial diseases of domesticated livestock (e.g., anthrax, tularemia, rinderpest, Newcastle disease, African swine fever, sheep pox, fowl pox, malignant catarrhal fever), and even insect species that could serve as vectors or vehicles for the deployment of bioweapon diseases e.g., mosquitoes, ticks, and fleas.[13] Several major components of the Soviet bioweapon research and development system in Russia are still largely intact, and some are now in the process of being expanded under "dual-use" research programmes (e.g., the *Vektor State Research Center for Bioengineering and Virology* in Koltsovo, Novobirsk and the *Russian Federation Ministry of Defense - Scientific Research Institute for Virology & Microbiology* in Pokrov), while others (such as the *State Research Center for Applied Microbiology* in Oblensk) have reportedly deteriorated to the point of becoming potential health and global security hazards because of loss of military-related research funding sources.

Most of the animal diseases cultured and tested for bioweapons applications under the Soviet bioweapons research and development

programme are also diseases identified by the World Animal Heath Organization (OIE) as having potential for serious socio-economic or public health consequences and rapid international or regional spread.[14] Recent biosecurity problems in former Soviet BW research and testing facilities involving Ebola and glanders, and prior incidents involving smallpox and anthrax underline the fact that existing and former bioweapons facilities in Russia and various newly-independent Central Asian nations (e.g., Kazakhstan, Uzbekistan) may continue to be a threat to global human and ecological security for decades to come - even in the absence of the establishment of any new overt or covert BW development and testing programmes.

Genetic engineering technologies and techniques may now have laid the foundation for a Pandora's Box[15] scenario in which the runaway proliferation of a genetically modified bioweapon disease could severely affect human and animal populations at regional, continental, or even global scales. The same genetic engineering techniques used to create new disease vaccines can also be used to develop disease strains that are able to infect vaccinated people or animals (i.e., vaccine-subverting disease strains), while gene-transfer experiments have demonstrated that even carefully controlled and monitored experiments using relatively benign viruses may create chimera viruses with entirely new dangerous or lethal properties.[16] Soviet and Russian scientists reportedly used genetic-engineering techniques to create vaccine-subverting and/or antibiotic-resistant strains of smallpox, anthrax, plague, and tularemia.[17]

Virulent cultured or wild strains of natural disease pathogens of livestock and wild ungulates (e.g., H5N1 avian influenza, anthrax, foot-and-mouth disease, rinderpest, brucellosis) may present serious threats to human, livestock, wildlife, and endangered species populations. Many formerly ubiquitous diseases of livestock that have been largely or totally eradicated from livestock populations in the United States and Western Europe over the past century are still common and even prevalent in other areas of the globe, and are readily accessible to individuals and terrorist organizations. Vaccines for many animal diseases still common in Third World countries have been phased out in Europe and North America, and these vaccines, along with drugs for routine treatment, may not be readily available in sufficient quantities to suppress large-scale disease outbreaks. Bioterrorist uses of even native "wild" strains of livestock diseases and emerging zoonotic diseases (diseases that may be transmitted between animal and human populations) represent a

potentially serious threat to livestock and wildlife populations never previously exposed to these diseases. This risk holds true for even for wildlife species that may not be seriously affected by the disease itself, but which may be targeted for extirpation as potential disease carriers or reservoirs.[18]

The use of term "diseases" is restricted in this analysis to acute and chronic human or animal health problems associated with microbial, viral, or pathogens. This usage does not include maladies caused by environmental toxins (arsenic, mercury, selenium), genetic dysfunctions (hemophilia, sickle-cell anemia), and behavioral or nutritional disorders or illnesses (kwashiorkor, obesity, substance abuse and addiction). We discuss the potential threats that bioweapons and emerging infectious diseases may pose to ecosystem health, indigenous peoples, and traditional livelihoods. Although the focus of this study will concern the potential effects of bioweapon disease outbreaks within and among animal populations, much of what will be discussed also applies to the potential direct and indirect effects of plant bioweapons on non-target species of wild and domesticated plants.[19] The potentially important effects of disease-mediated changes on the structure and composition of ecological communities, habitat mosaics, patch dynamics, and ecosystem processes will not be addressed in this analysis due to space limitations.

Smallpox

Smallpox, and particularly genetically engineered smallpox, appears to represent the most serious bioweapon threat to human populations at the present time. A deliberate or accidental release of the smallpox virus could have health impacts at the continental and global scales.[20] Although smallpox (*Variola major*) has long been feared as one of the most deadly of all infectious human diseases, its potential for devastation today if used as a bioweapon is far greater than at any previous time in history due to the long post-infection period prior to the onset of disease symptoms coupled to the closed ventilation system of airplanes, and the extreme rapidity and frequency of global air travel. Smallpox is exceptionally dangerous in this regard because of its extreme infectivity, long latency period (7-21 days), high case-fatality rates ($\geq$ 30 per cent), and the absence of any effective therapeutic treatment for the disease (Henderson *et al.* 1999). Routine vaccination for smallpox ceased more than 25 years ago in many countries around the globe,[21] and a recent

study in Maryland has indicated that most people in the United States vaccinated in years past have probably lost their immunity to this disease.[22] One must remember in this context, however, that standard *Vaccinia*-derived vaccines (recent or otherwise) may not provide immunity against a genetically modified, vaccine-subverting smallpox strain such as that reportedly developed by the Soviet/Russian bioweapons programme.[23]

Historical accounts indicate indigenous peoples and rural farming communities, as well as urban population centers, often suffered extremely high mortality rates as the result of social disruption and starvation from epidemics of smallpox, measles, cholera, plague, and other introduced diseases. The available historical records indicate that infection rates (morbidity) cited for smallpox epidemics among natïve human populations may approach 100 per cent, with death rates (mortality) among smallpox victims of up to 30-60 per cent and occasionally higher.[24] Only 31 individuals of a group of 1600 Native Americans of the Mandan tribe of the northern Great Plains region of North America survived an smallpox outbreak in 1837.[25] Several tribes of the indigenous Khoikhoi [Khoisan] peoples of southern Africa were extirpated by a smallpox epidemic that began in 1755, and mortality rates of 80 per cent were reported from a subsequent 1831 epidemic among the Griqua, an outcaste people of mixed European and Khoisan ancestry.[26] Native Hawaiians were reduced by introduced diseases from Europe and Asia (e.g., smallpox, cholera, measles) from an estimated population of 500,000 inhabitants in 1779 to only about 84,000 in 1853; nearly half of the extant native Hawaiian population (150,000 individuals) may have perished during a single epidemic of cholera in 1804.

Historical and anecdotal evidence suggests that indigenous peoples of Australia and the Americas suffered exceptionally high rates of mortality from smallpox, and epidemics of smallpox and other European-introduced diseases may have effectively depopulated large areas of South America and Australia long before Europeans themselves arrived on the scene.[27] A widespread outbreak of smallpox resulting from release and proliferation of a smallpox bioweapon could have major impacts not only on human populations, particularly those of indigenous peoples isolated from medical and social support systems, but also present a serious threat to populations of chimpanzees (*Pan troglodytes*) and other endangered species of great apes that may be susceptible to this disease.[28]

Pestilence and Famine

Human mortality as the result of starvation due to food shortages caused by disease outbreaks among livestock or staple food crops may equal or exceed that caused by human disease epidemics. Famine resulting from the destruction of cattle by the Great African Rinderpest Panzootic of 1889-1898 devastated African peoples who depended on cattle or wildlife for food and subsistence, generating rates of human mortality from starvation that equaled and in some instances surpassed those associated with smallpox epidemics in these same regions. An estimated 30 per cent to 60 per cent of Ethiopia's population starved to death in 1888 as the result of the rinderpest epizootic. Approximately two-thirds of the Masaai people of eastern Africa (a Nilotic people whose traditional diet consists almost exclusively of milk and blood from their cattle) starved to death during 1889-1898 as the rinderpest epidemic spread southward through eastern Africa.[29]

This account of the Great African Rinderpest Panzootic in Africa of 1889-1898 is given in some detail because it provides an excellent example of the catastrophic consequences that follow the introduction, by accident or design, of a highly virulent virus into a "Virgin Ground" situation. Such a situation could very soon occur in Asia where mass vaccination has now been superseded by routine surveillance and the elimination of residual foci of infection. Rinderpest, a highly contagious and lethal virus disease of cattle and cloven-hoofed wild animals, has frequently threatened the pastoral and tourist-based economies of some countries in eastern Africa and western Asia.

The rinderpest virus is a *Morbillivirus* of Asian origin first introduced years ago into Africa in 1887 in Asian cattle imported by the Italian army during an invasion of Abyssinia [Ethiopia]. On this occasion almost all the ruminants, both wild and domestic, were highly susceptible to the virus and the disastrous Great African Rinderpest Panzootic that ensued, swept southward through the pastoral countries of Eastern and Southern Africa until it reached the Cape of Good Hope on the southern tip of the African continent in 1896. Hundreds of thousands of cattle, buffalo (*Syncerus caffer*), eland (*Tragelaphus oryx*), lesser kudu (*Tragelaphus imberbis)* wildebeest (*Connochaetes taurinus*), giraffe *(Giraffa camelopardalis*) and warthog (*Phacochoerus aethiopicus*) died with reported rates of mortality among domesticated cattle approaching nearly 100 per cent in some areas. The Masaai and other nomadic Nilotic peoples who depended upon the milk and blood of

their cattle for virtually all of their normal diet were devastated by the outbreak, with starvation and malnutrition contributing to high rates of mortality from concurrent outbreaks of smallpox and other diseases.[30] The Great African Rinderpest Panzootic similarly affected the hunting/gathering tribes-people and the hoe-cropping agrarian peoples who lived in the tsetse/trypanosomiasis-infested regions of Africa and cultivated crops but did not keep livestock. These people were largely dependent on meat and animal products from the wild ungulates that now succumbed to rinderpest.[31] Traditional farming and cattle-raising societies such as the Sukuma and Samburu peoples of Eastern Africa, the Ndebele and Zulu of Southern Africa and the Fulani of the central sub-Sahel were severely affected by the Great African Rinderpest Panzootic.[32]

The effect of the Great African Rinderpest Panzootic of 1889-1898 on the numerous wild ungulates of Africa was equally catastrophic. There are over 90 species of wild ungulates in Africa that are potentially susceptible to rinderpest, although the species vary greatly in their response to infection. Many species, particularly buffalo, lesser kudu, eland and warthog have a lower innate resistance than zebu cattle, and when infected, quickly sicken and die. In contrast, others develop subclinical infections, recover and become temporary carriers of the virus. Prior to the advent of the very safe and effective cell-culture vaccine for cattle in the early 1960s, the wildebeest population on the Serengeti Plains in Tanzania stood at about a quarter million. It stayed at this level due to the annual spread of rinderpest virus from infected contiguous cattle to the wildebeest calf crop of the year, causing what was then known as 'Yearling Disease'. In 'bad' years when poor rains resulted in a shortage of grazing, some 90 per cent of the wildebeest calves would die of rinderpest. However, the survivors and their parents (survivors of previous years) were resistant to infection.

Then, in the mid 1960s, cell-culture rinderpest vaccine was developed and the annual vaccination of millions of cattle throughout East Africa under the multi-donor Pan African vaccination programme (called JP 15) began. This initiative almost succeeded in eliminating clinical rinderpest from the African continent. The immunization of the contiguous Tanzanian cattle in and around the Serengeti Plains removed the source of rinderpest virus which each year had killed a large proportion of the wildebeest calf crop. As a result, the wildebeest population and to a lesser extent the buffalo too, multiplied greatly and in a very few years the wildebeest on the Serengeti Plains had

increased from a quarter million to 1.6 million, at which level it stands today.[33] Concurrently, the very important and lucrative wildlife-based tourist industry developed in Kenya and Tanzania.

Unfortunately, the early successes of the JP 15 vaccination campaign were not followed up and there were no concerted efforts made to eliminate the last few small remaining pockets of rinderpest infection. It was from these that the virus emerged again in 1982-84 and rapidly spread across sub-Saharan Africa until 30 countries were affected. This outbreak of disease is estimated to have cost US $500 million before it was brought under control. In response to this excursion of rinderpest into the pastoral areas of Kenya and northern Tanzania, the Food and Agriculture Organization (FAO) of the United Nations (UN) and the Inter-African Bureau for Animal Resources (IBAR) planned and implemented the Pan African Rinderpest Campaign (PARC). Like JP 15, PARC was designed to control and eventually eradicate the disease. However, while most of the clinical cases of rinderpest are seen in domestic cattle and wild buffalo, at the outset the control measures proposed by PARC took no account of the inevitable epidemiological involvement of susceptible wildlife in the affected regions. This omission was partly corrected when FAO in 1984 funded a short project to study the wildlife-cattle linkages throughout the sub-Saharan region. Ten years later PARC found itself in the same situation as that which applied when JP 15 was wound up. Rinderpest was once again restricted to three well-known enzootic pockets in East Africa (and one in Pakistan). All three East African foci were in areas of civil strife (Southern Sudan, Northern Ethiopia and the Kenya-Somali border). This made eradication much more difficult.

In 1994, rinderpest, believed to have been brought south by trucked cattle from the Kenya-Somali border, broke out in the unvaccinated cattle and wild buffalo in and around Tsavo East National Park in Kenya. As a result, very large numbers of susceptible cattle and wildlife were exposed to infection. In October/November 1996, rinderpest broke out in Nairobi National Park and killed numerous buffalo and eland. The disease also affected local cattle herds. The causal virus strain was identified as similar to the one that had killed 50 per cent of the buffalo and 80 per cent of the lesser kudu in Tsavo National Park in 1994/95. In mid March 1997, rinderpest was confirmed in Maasai cattle in a village overlooking Ngorongoro Crater in north/central Tanzania. The huge populations of wildebeest and other antelopes in the Serengeti

and Ngorongoro Crater ecosystem, which had been free from rinderpest infection for 14 years were especially at risk. There were an estimated 10 million unvaccinated cattle located within the immediate vicinity of the outbreak. An extremely serious risk was thus presented to the livestock-based agricultural economies and wildlife-based tourist industries of the countries of Eastern and Southern Africa. Fortunately, a massive vaccination campaign was successfully implemented which contained the rinderpest outbreak and eventually eliminated it before it had spread into wildlife populations or southward through the Mbeya Gap into the millions of unvaccinated cattle (and the susceptible wildlife) of Southern Africa.

The question of whether rinderpest is maintained for long periods in wildlife is often raised. However, all the available evidence indicates that even in large wildlife populations, the disease dies out once efficient vaccination eliminates it from contiguous cattle. Susceptible wild ungulates are now being regularly sampled throughout sub-Saharan Africa to detect the presence or absence of antibodies to rinderpest. Wild animals are thus being used to act as sentinels to track the movements of the virus through susceptible animal populations. Vaccinated cattle carry antibodies for life and at present naturally infected cattle cannot be distinguished from vaccinates on test.

The development of a new improved, heat-stable vaccine for rinderpest, that allows naturally infected cattle to be distinguished from vaccinates, will be a great advance and will remove the need to continuously monitor the virus in susceptible wildlife species. Such a vaccine is under development now. Once all the cattle in the remaining pockets of rinderpest infection become accessible for vaccination, there is an excellent chance that, like small pox, the virus of rinderpest will be eliminated from the world. FAO predicts that this final effort could cost as little as US $3 million and could be completed by 2010.

Until very recently, rinderpest has been present on the Indian Sub-Continent. Despite the prevalence in India of a number of different stock diseases, rinderpest used to cause more deaths of cattle and domestic buffaloes than all the other diseases put together and the annual cattle losses in the 1860s were estimated to run into hundreds of thousands. A century later this had been reduced to 200,000. A rinderpest panzootic was reported in 1870 in Mysore, Madras, Bengal, Oudh, and the North West Frontier Provinces to the foot of the Himalayas, Ceylon (now Sri Lanka) and Burma (now Myanmar).

Effective control of rinderpest in India began in 1934 with the introduction of a caprinized vaccine but a National Rinderpest Eradication Programme did not begin until 1954. As a result of mass vaccination, followed by annual vaccination of calves, the establishment of controls on interstate borders and vaccination stations on international borders, incidence of the disease was greatly reduced but total eradication was not achieved.

In 1991, the South Asia Rinderpest Eradication Campaign was introduced by the FAO. In 1985, rinderpest still persisted in the tip of Peninsula India and in 1992 a National Project on Rinderpest Eradication was launched with the aid of EEC funds. This resulted in a drop in reported outbreaks in cattle from 103 in 1993 to 29 in 1994, 10 in 1995 and zero in 1996. From March 1998, India declared itself provisionally free of rinderpest. In Pakistan, rinderpest is known to have occurred in cattle and buffaloes since the beginning of the twentieth century and two epizootics were recorded in the 1950s when "hundreds of thousands " of animals died. Since then it has continued to smoulder and in 1993 an epizootic was reported in Punjab State. The following year a separate epizootic appeared in the Northern Areas in Gilgit and the Hunza Valleys. This outbreak killed an estimated 40,000 to 50,000 hill cattle within a year, before being controlled by vaccination. The last reported outbreak of rinderpest in Pakistan was in the Sindh Province in October 2002; and, in November of that year it was announced that "It is conceivable that Asia is now free from rinderpest for the first time in millennia".[34]

Nonetheless, the risk from the movement of livestock to feed troops and civilians, and movements of breeding stock required for the rehabilitation of agriculture in Afghanistan and for development projects in Pakistan coupled with the final stage of the rinderpest eradication process by which all countries cease routine mass vaccination in favour of surveillance and elimination of residual foci of infection, has provoked one source to remark that "Never have the countries of South Asia been so vulnerable to a resurgence of rinderpest".[35]

Epizootic Disease and Ecosystem Health

The Great African Rinderpest Panzootic of a century ago illustrates the potential synergistic, regional effects of the release or escape of virulent and contagious zoonotic or agricultural bioweapon diseases on human and livestock populations.

As the history of rinderpest in Africa demonstrates, the introduction and proliferation of virulent epizootic diseases in new environments can have marked long-term effects on local and regional biotas with cascading landscape-level impacts on biogeochemical nutrient cycles and ecosystem dynamics.[36] Many of the currently available bioweapon pathogens are broad-spectrum diseases of humans and/or livestock capable of causing high levels of mortality or morbidity among wild as well as domesticated species of animals. Three of the four genetically-modified, weaponized disease (anthrax, plague, and tularemia) pathogens reportedly developed for use against human populations are broad-spectrum zoonotic diseases whose release into the environment may pose direct and indirect threats to livestock and wildlife as well as human populations.[37] The use of broad-spectrum diseases of animals or plants for purposes of sabotaging livestock or agricultural production could have potentially disastrous spill-over effects on populations of wild plants and animals. Virulent natural disease pathogens used for bioweapon attacks against livestock populations (e.g. rinderpest, FMD, brucellosis) could have devastating effects on populations of wild as well as domesticated animals, with severe collateral impacts on pastoral, agrarian, and hunter/gatherer societies.[38]

The control of disease in livestock and wildlife is a critically important factor in maintaining the health and cultural vitality of rural populations throughout most areas of the developing world.[39] According to the FAO the use of draught animals — oxen (*Bos taurus; B. indicus*), water buffalo (*Bubalus bubalis*), donkeys (*Equus asinus*), camels (*Camelus dromedarius*) for the cultivation of field crops such as rice, maize, wheat, millet, sorghum, and potatoes is expanding in Africa, while it is still widespread throughout much of Asia and Latin America.[40] The Sami, Lapps, Nenets, and other indigenous peoples of arctic regions of northern Eurasia still depend heavily, if not entirely, on domesticated reindeer (*Rangifer tarandus*) for food, clothing shelter, transport, and marketable goods.

The industrialization and globalization of agriculture has drastically reduced the diversity and abundance of local and endemic livestock breeds over the past century.[41] Modern, cosmopolitan livestock breeds exhibit outstanding performance on high-quality rangelands, feeder-lot situations, or industrial dairy farms but typically perform very poorly on marginal rangelands, areas subject to climatic or altitudinal extremes, and ecosystems with endemic diseases and problems

from insects or parasite infestations. Conservation of the indigenous livestock breeds developed and maintained by pastoral peoples over the past four or five millennia (or more) is important for sustaining traditional livelihoods and cultures, and for the retention of genetic, morphological, and physiological adaptations that can provide enhanced resistance to insects, parasites, disease, climate, altitude, solar radiation, and other important environmental variables that function as major constraints on livestock survival and productivity.

Many of the surviving indigenous breeds of livestock maintained by traditional pastoral and agrarian peoples have critically small population sizes and highly localized distributions.[42] Local breeds now often consist of highly inbred lineages with critically small populations sizes that are susceptible to decimation or extinction from even extremely localized disease outbreaks.[43] Although some breeds exhibit high levels of resistance to endemic diseases, they may nonetheless be highly susceptible to morbidity and mortality from exposure to new disease strains and exotic disease pathogens. In 1994, for example, rinderpest spread to remote mountainous areas of northern Pakistan that had previously been free of the disease, killing an estimated 40,000 cattle and yaks.[44]

Diseases that cause high rates of morbidity and mortality in humans or domesticated animals can occur in wildlife species without clinical manifestations of disease infection (e.g., hantavirus; trypanosomiasis), and diseases that are relatively benign in humans and domesticated animals may be extremely dangerous for wildlife species (parvovirus, herpesviruses, morbilliviruses). Control programmes for livestock diseases may have deleterious impacts on ecosystems, however, when they encourage or permit the build-up of unsustainably high ungulate densities and overgrazing of vegetation that may cause, or contribute, to the desertification of ecologically fragile landscapes. Control measures for zoonotic diseases may also result in concerted efforts to eradicate any or all wildlife species that may be potential reservoirs, intermediate hosts, or vectors for disease transmission to humans or domesticated animals. Such efforts, if conducted at regional or national scales, may have severe impacts on rural communities and indigenous peoples who depend on wildlife for subsistence, material goods, and marketable commodities.

The potentially devastating effects of even localized bioweapon disease outbreaks on isolated endangered species populations are

illustrated by the effects of recent outbreaks of canine distemper virus on the African wild dog (*Lycaon pictus*), the Caspian seal (*Phoca caspica*), and North American black-footed ferret (*Mustela nigripes*). Canine distemper is a *Morbillivirus* disease of domesticated dogs that has been cultured and tested in bioweapon laboratories. It is very closely related to the virus that causes measles in humans. Canine distemper outbreaks in domesticated species can spill over into wildlife populations, with devastating results on susceptible species of wild carnivores and marine mammals.[45] Canine distemper outbreaks caused the near extinction of the African wild dog population of the Serengeti National Park, Tanzania and the last known wild population of the North American black-footed ferret.[46]

Diseases do not operate independently of a variety of ecological factors, however. Habitat loss and persecution as pests and vermin, exacerbated by the prior effects of sylvatic plague on black-footed ferrets and their prey base (prairie dogs), caused the decline and ultimate extinction of black-footed ferrets from their formerly extensive range within the Great Plains region of North America. Similarly, persecution and predator-control operations have reduced the African wild dog to a few small and scattered populations that are now gravely threatened by spill-over infections of rabies and canine distemper from domestic dog populations.[47] An outbreak of distemper in the Serengeti region of Tanzania caused the extirpation of the resident wild dog population and the death of approximately one-third of the Serengeti's resident lion population, and cheetahs (*Acinonyx jubatus*) could have been driven to the verge of extinction in the Serengeti had they experienced rates of morbidity and mortality comparable to that observed among African wild dogs at this site.[48]

Zoonotic Disease and Ecosystem Health

Zoonotic diseases are pathogen-caused diseases that can be transmitted within and among populations of humans and other organisms (mammals, birds, fishes, etc.). Zoonotic pathogens cause some of the most virulent and deadly known human diseases (plague, anthrax, rabies, tuberculosis, Ebola hemorrhagic fever, Marburg, hantavirus pulmonary syndrome; Crimean hemorrhagic fever) as well as numerous other typically less severe but still potentially fatal illnesses (malaria, salmonella and streptococcal infections, West Nile Virus, avian influenzas, tularemia, Rift Valley Fever) some of which are only now

emerging or being recognized as epidemiologically significant pathogens within human populations (e.g., H5N1 bird flu, *Escherichia coli, Campylobacter*).

The recent - and still evolving - history of West Nile Virus (WNV) in North America provides a frightening example of the potential dispersal capabilities of bioweapon diseases within and among human and animal populations, and illustrates the immense (and in some cases possibly insurmountable) difficulties in identifying and controlling cryptic although potentially lethal zoonotic diseases following their deliberate or accidental introduction to new regions. An arbovirus disease formerly native to Africa and southern Eurasia, WNV was first reported from New York City in the summer of 1999. WNV has now spread across North America from coast-to-coast throughout nearly all areas of the continental mainland between 50°N southward into Central America and throughout the Caribbean,[49] and is now likely to be already present on the South American mainland.

WNV is a mosquito-transmitted disease of birds and mammals (including humans) that is native to Africa and the Middle East and causes high rates of mortality in some host species.[50] Since 1999, >150 species of North American birds have been reported as WNV positive to the Centers for Disease Control and Prevention (CDC) ArboNET surveillance programme.[51] Humans are highly susceptible to WNV, although only about one in 1000 infected people actually develop serious clinical disease symptoms. Among people in the USA reported as suffering clinical illness from WNV during 2002, the average death rate was approximately 6.5 per cent.[52] Although WNV is primarily a disease of birds, mammals are common secondary but apparently dead-end hosts for this virus. As of September 21, 2002, fatal WNV infections had been documented from 111 species of birds in North America (88 native species, 23 exotics or introduced species). In North America, fatal WNV infections are most commonly observed in horses although numerous species of wild and domesticated mammals are known to be susceptible to this disease (see below). Current indications are that the West Nile Virus has become permanently established in eastern and central North America over the past three years, and it appears probable that migrating birds could ultimately spread the disease throughout the Americas and the Caribbean.

Speculation that West Nile Virus (WNV) may have been introduced to the USA as the result of a bioweapon deployment by foreign agents

does not seem likely in view of the fact that the most severe epidemiological impacts of WNV are associated with horses rather than humans, and that WNV (although potentially fatal) is comparatively benign in humans relative to a number of other "wild", widely-distributed diseases that might be fairly easily acquired and used as low-tech/no-tech bioweapons agents.[53] The observed timing and pacing of dispersal of West Nile Virus (WNV) appears to be the result of an inadvertent introduction of infected birds or mosquitoes to the New York City metropolitan area sometime during or prior to the summer of 1998. The original source of the infection is unknown, but the most likely source appears to be infected mosquitoes accidentally imported from Africa or the Middle East (in aircraft or ship containers), or infected African birds imported to the United States for zoos or the commercial pet trade (African grey parrots, zebra finches, etc.). The available evidence seems consistent with the inadvertent introduction hypothesis.

The initial spread of WNV within the middle Atlantic Coastal Plain during 1999 appears to have been mediated primarily by crows (*Corvus* spp.), with the subsequent explosive dispersal southward and westward was the result of progressive epidemic infections among migratory birds on summering grounds in the northeastern U.S. and wintering grounds in the Gulf Coastal region of the southeastern USA during the winters of 2000 and 2001. The rapid proliferation and spread of the WNV outbreak in North America during 2001 and 2002 may have been driven or mediated by infections of highly gregarious and widely ranging migratory bird species such as the common grackle (*Quiscalus quiscula)* and the red-winged blackbird — *Agelaius phoeniceus*.[54]

An outbreak of exotic Newcastle Disease Virus (END) during 1971 attributed to illegally imported Mexican parrots (*Amazona oratorix*) precipitated a disease outbreak in California and Arizona that resulted in the destruction of approximately 12 million poultry birds, and the institution of a 3-year vaccination programme to eradicate the disease.[55] Movements of secondarily infected exotic birds through the pet trade were instrumental in further expanding the initial outbreak.[56] A subsequent END outbreak that began in September 2002 was first reported from backyard "game fowl" breeding facilities in southern California.

The current 2002-2003 END epidemic appears to have resulted from infected fighting cocks, or brood hen breeding stock, imported to the

USA from Mexico. The disease spread into commercial poultry facilities in October 2002, resulting in the imposition of quarantine and euthanization/disposal sanctions on commercial poultry facilities in southern California and the European Union and a number of other countries banned imports of all U.S. poultry products pending the control and eradication of the END outbreak.[57] Despite these precautions, END continued to spread and by early February 2003 infected flocks had been discovered in Nevada and Arizona. The spread and proliferation of END appears to be connected to the interstate movement of infected fighting cocks, and the infection of new birds from other areas, in conjunction with the illicit but popular cock-fighting industry. Cock-fighting, and the gambling intimately associated with it, is a popular activity with deep and ancient roots in Hispanic and Oriental cultures (among others). Cock-fighting has also been implicated in the spread of the H5N1 avian influenza virus from Thailand into Malaysia, and in at least one human death from H5N1 "bird flu".

It is possible that the introduction of WNV to the Western hemisphere may have profound impacts on the indigenous peoples of the Americas, in terms of both the epidemiological effects from the disease itself and the impacts of the disease on wildlife and livestock populations. WNV is known to causes high rates of mortality in some species of mammals, with death rates in at least two species of mammals (e.g., horses and mountain goats) comparable with those associated with smallpox in humans (30-50 per cent). Many mammal species appear to be susceptible to WNV, and there is an extensive and still growing list of mammals recorded with fatal WNV infections including humans, horses (*Equus caballus*), domestic dog (*Canis familiaris*), wolf (*Canis lupus*), gray squirrel (*Sciurus carolinensis*), domestic cat (*Felis catus*), domestic sheep (*Ovis aries*), llama (*Lama glama*), alpaca (*Lama pacos*), rabbit (*Oryctolagus cuniculus*), raccoon (*Procyon lotor*), chipmunk (*Tamias striatus*), striped skunk (Mephitis mephitis), bats (*Myotis lucifugus; Eptisecus fuscus*), and Rocky Mountain goat (*Oreamnos americana*).[58]

During the summer of 2002, high rates of WNV mortality were reported among several species of raptors (owls, hawks) in the central United States in conjunction with an ongoing epidemic outbreak of the disease among humans.[59] Deaths of captive birds in North America have demonstrated that macaws (*Ara* spp.) and Chilean flamingoes (*Phoenicopterus chilensis*), birds of major significance as subsistence

resources to indigenous peoples in South America,[60] are susceptible to mortality from WNV. Llama and alpaca, endemic domesticated mammal species of major importance as subsistence and commercial resources to indigenous peoples of the Andean highland regions of South America, are likewise subject to mortality from WNV. West Nile Virus mortality has been reported among species that inhabit the boreal and Arctic regions of the Northern Hemisphere. Northern species known to be susceptible to WNV mortality include such as reindeer (*Rangifer tarandus*), (a domesticated European species closely related to the North American caribou), harbor seal (*Phoca vitulina*), and Snow goose (*Chen caerulescens*), all of which are wildlife species of importance to the cultures and subsistence economies of indigenous peoples in Arctic and boreal regions.[61]

The history of rinderpest in Africa and West Nile Virus in North America shows that exotic diseases may proliferate rapidly across entire continents, and be difficult or impossible to eradicate once introduced and established within new localities. In the case of anthrax, the risk of subsequent disease outbreaks within contaminated areas may continue for decades and even centuries even after potential hosts and vectors have been totally eradicated: viable, infectious anthrax bacilli have been cultured from animal bones buried for 150-200 years in archeological sites.[62] Bioweapon disease strains, and especially genetically modified weaponized diseases, may spread more rapidly and prove much more difficult to suppress and eradicate than natural disease strains given the exceptional virulence and environmental resilience of cultured bioweapon disease strains.[63] Isolated populations of endangered species, as well as indigenous local breeds of livestock, may be especially susceptible to extinction as the result of uncontrolled outbreaks of zoonotic or agricultural bioweapon diseases.[64]

There needs to be much wider recognition of the potential impacts of diseases of domesticated animals and humans on wildlife and endangered species populations, and the pivotal role of human interventions in fostering the introduction and establishment of exotic diseases of plants and animals in new areas Eco-tourism and research programmes involving human-habituated ape populations have resulted in interspecies transmission of introduced, exotic diseases such as polio and measles from humans to gorillas (*Gorilla gorilla, G. beringei*) and chimpanzees (*Pan troglodytes, P. paniscus*), and has been correlated with higher ra*tes of* intestinal parasite infections among habituated ape

populations.[65] Contact with meat from an infected gorilla was blamed for initiating a previous outbreak of Ebola in northern Gabon during January – May 2002 that killed at least 53 people.[66] Nearly all recent Ebola outbreaks in Gabon and Congo in recent years have been linked to index cases involving people who had had contact with infected animals or meat from infected animal carcasses, including lowland gorillas, chimpanzees, monkeys, and duikers —small forest antelope.[67] Catastrophic mortality from Ebola has been reported among chimpanzees and gorillas in the Lossi Gorilla Sanctuary in the northern Republic of Congo, including gorillas belonging to several family groups that had been habituated to human presence as part of a European Union-funded ecotourism project managed by ECOFAC (Ecosystemes Forestiers d'Afrique Centrale). During the outbreak between November 2000 and February 2003 in the districts of Mbomo and Kellé in the Cuvette Ouest Region of the northern Republic of Congo, there were 90 reported probable human cases of Ebola haemorrhagic fever including 77 deaths (case fatality rate 81 per cent).[68]

Indigenous rights groups have raised issues regarding similar linkages between ecotourism and disease transmission to isolated communities of indigenous peoples.[69] Given the rapidity and frequency of international travel, and limited enforcement of health regulations (where present) on the health status and activities of tourists participating in ecotourism adventures in remote areas, the potential threats of global transmission and proliferation of human as well as animal diseases are already significant and increasing with the passage of time.

Conflict and Contagion

Diseases and famine, not wounds and injuries from combat or persecution, have historically been the greatest source of human mortality among both soldiers and civilians during periods of war and civil conflict.[70] Breakdowns in medical and veterinary support systems during wars and civil conflicts resulted in epidemic outbreaks of zoonotic diseases within and among human, livestock, and wildlife populations in southern Africa.[71] The Iran/Iraq War and the Arabian Gulf War precipitated rinderpest epizootics among livestock populations in the region that were caused or aggravated by war-related displacements of pastoralists and their flocks.[72] Recent outbreaks of several lethal zoonotic diseases in Central Africa (monkeypox, plague, Marburg fever, Ebola)

have been linked to increased human consumption of wild animals (e.g., squirrels and rodents) as the result of war-time food shortages, coupled with the depletion and disappearance of preferred bushmeat sources (primates, duikers) as the result of over-harvesting for the commercial bushmeat trade.[73]

An anthrax outbreak in Southern Rhodesia (now Zimbabwe) during the period 1978-1980 might have been the result of biological warfare.[74] Although anthrax is endemic to the Matabeleland region of the country where the outbreak first appeared and proliferated, there have been widely publicized allegations linking the 1979-1987 anthrax epidemic to apartheid South African Defense Force and covert operations of the Rhodesian Central Intelligence Agency.[75] In contrast with the series of anthrax "poison letter" attacks in the United States during September-October 2001, however, there appears to be little if any real evidence to support allegations of the use of weaponized anthrax against human populations. Virtually all of the documented cases of human anthrax associated with this epidemic involved cutaneous or intestinal anthrax infections resulting from contact with diseased cattle.[76] Subsequent resurgences of human anthrax in Zimbabwe include at least 1,000 documented human cases and at least 11 deaths recorded during 2000 and 2001[77] and continued problems with anthrax in cattle and humans were still being reported as of June 2005.

The government of Zimbabwe has attributed the country's most recent anthrax outbreak to sabotage by recalcitrant white commercial farmers contesting the country's controversial compulsory land redistribution programme.[78] Economic distress and the disruption of anthrax vaccination programmes and veterinary services as the result of internal political turmoil may be important factors behind the current anthrax outbreak in Zimbabwe, as appears to have been the case during the 1979-1986 outbreaks. Breakdowns in government veterinary services and vaccination programmes have permitted the proliferation and spread of anthrax among cattle in the tribal communal lands, with deteriorating economic conditions and food shortages encouraging villagers to risk disease or death from anthrax infections in order to butcher diseased cattle to obtain meat and hides for consumption or sale in local markets. An outbreak of blackquarter fever (a fatal but preventable clostridial disease of cattle) that killed 5,000 cattle during August and September 2002 has been attributed by government sources to a lack of foreign exchange to purchase vaccines against the disease.[79]

Cultural Impacts and Constraints

Traditional belief systems may hinder the process of recognizing and containing disease outbreaks, and serve to expand and exacerbate and expand their potential effects on traditional and indigenous societies. Traditional belief systems frequently attribute disease in humans or animals to non-biological phenomena (divine, spiritual, "supernatural", or karmic influences) rather than host-pathogen-vector-media ecological relationships. The presence and abundance of game animals and productivity of agricultural crops may be likewise be ascribed to the influence or intercession of ancestral spirits, divine beings, spirit guardians of species or places, and other types of non-ecological causative factors. The Bisa people of the Luangua Valley of Zambia attribute the abundance and approachability of game animals to the intercession and influence of ancestral spirits,[80] while the Yup'ik and other Alaskan Native peoples believe that the abundance of harvestable fish and wildlife populations is modulated by cultural and spiritual influences exerted through appropriate and respectful modes of utilization.[81]

Indigenous belief systems may not recognize the possibility that fish and game populations (traditionally regarded as elusive but fundamentally inexhaustible resources) can be rapidly and permanently depleted by newly-introduced diseases, or changes in the intensity and efficiency of harvest regimes resulting from new technologies (e.g., modern firearms instead of bow-and-arrow or blowpipe; steel wire or cable snares; nylon gill nets). The disappearance of game or fish species as the result of outbreaks of previously unknown diseases therefore has the potential to exert serious impacts on the spiritual and religious foundations of societies based on traditional knowledge and cosmology. Caribou (*Rangifer tarandus*) are central to both the traditional culture and subsistence economy of native peoples in northern Alaska and Canada. Clarence Alexander, a traditional leader of the Gwich'in Athabascan people of central Alaska, has articulated this relationship as follows, "*You destroy the caribou, you destroy the Gwich'in people. My connections to the land are the animals' connection to the land. The animals are the ones that maintain themselves on this land. And how I maintain this land is the key to survival*".[82] Negotiations for the regulation of the salmon fishery in Alaska's Kuskoquim River system were complicated by cultural disconnects between government biologists who wanted to publicly announce that the fishery was depleted and close the harvest, and

Yup'ik elders for whom such an announcement would be tantamount to an admission of moral degradation or misconduct within their local community because of the traditional belief that "fish withhold themselves from humans who behave improperly".[83] It is worth noting in this context that the possibility (much less the reality) of total extinction for any biological species through any agency whatsoever - whether natural, human, or divine - remained a hotly disputed scientific and theological concept in Europe and the United States until well into the twentieth century.[84]

Lack of belief in the efficacy of modern medical therapies, as well as the lack of ready access to medical support facilities, may hinder our ability to identify and cope with newly emerging disease threats in remote rural areas around the globe. The impacts of introduced exotic diseases of animals or humans may have significant impacts on the very fabric of social and inter-personal relationships within traditional societies that do not recognize the basic paradigms of Western medicine regarding the environmental and ecological causes of illness and disease nor the effect of population dynamics on the abundance and survival of local and regional wildlife populations. In at least some indigenous societies in Africa and South America, disease-related human illnesses are traditionally believed to be the result of sorcery or witchcraft by neighbors or close relatives.[85] Sorcery is a matter that is not taken lightly in traditional African societies, and suspected sorcerers among African peoples were traditionally subject to trial by poison ordeal and/or torture to reveal their activities and executed if presumed guilty. In February 2003, Congolese villagers reportedly stoned to death 4 teachers accused of using sorcery in conjunction with an epidemic outbreak of Ebola haemorrhagic fever in the Kelle and Mbomo districts of the Republic of Congo-Brazzaville. "In Kelle, people continue to believe that Ebola fever is a spell that has been cast on them by witches, and the 4 teachers accused of being the cause of the disease have been beaten and stoned to death," said Dieudonne Hossie, a government official speaking on the official Radio-Congo. "We call on the people of Kelle to be calm. It is the Ebola virus that is raging in the area. It is not an evil spell, it is a scientifically proven virus".[86] The Congolese government placed the Kelle and Mbomo districts under quarantine restrictions, with schools and churches closed, and people banned from entering or leaving the area. As of 22 Feb 2003, the WHO reported 5 laboratory confirmed and

90 suspected cases of Ebola in the region, with a death toll of 77 (81 per cent fatality rate) among documented victims of the disease.

The Valley Bisa of Zambia believe that the incidence of sorcery has increased since the coming of the Europeans, and attribute this increase to the suppression of the sorcery trials by poison ordeal that were used traditionally to identify and punish suspected sorcerers.[87] A perhaps equally parsimonious modern scientific explanation would be that increased rates of illness subsequent to the establishment of a European colonial presence in the region have been caused by additive morbidity and mortality from newly-imported foreign diseases (e.g., measles, smallpox, polio, influenza), and increased rates of disease incidence and proliferation among formerly isolated Valley Bisa communities as the result of higher levels of mobility and migration, and consequently higher rates of disease interchange, between and among formerly remote rural areas and new, cosmopolitan urban and industrial population centers.

Our ability to cope with the impacts of disease threats from bioweapons and emerging infectious diseases may also be handicapped by the ongoing proliferation of drug-resistant disease strains caused by improper use and inappropriate uses of antibiotics to suppress diseases and infections in both humans and animals. Antibiotic use the US is now so prevalent that detectable amounts are recoverable from rivers, reservoirs and groundwater, and in effect, our current situation represents an ongoing, essentially uncontrolled field experiment in the cultivation and proliferation of antibiotic-resistant microbe populations. This problem may well be aggravated by fear of exposure to bioterrorist attacks, as demonstrated by the recent episode of panic-inspired purchases and consumption of antibiotics by American citizens precipitated by a series of anthrax attacks in the United States during September-November 2001. Subsequent events proved such concerns were not entirely unwarranted, as five of the 21 people known to have contracted anthrax as the result of exposure to contaminated mail subsequently died as the result of undiagnosed or tardily diagnosed pulmonary anthrax infections. The ultimate sources of infection for at least two of the inhalation anthrax fatalities associated with the 2001 anthrax bioterrorist attacks have yet to be identified.[88]

At the present time, indigenous peoples throughout the globe from the equatorial tropics to the high arctic remain heavily dependent on wild animals and birds as sources of food, clothing, tools, raw materials,

medicines, religious sacraments, and traditional cultural accoutrements. Subsistence use of wildlife (with or without a supplemental trade in wildlife products) continues to be an essential, integral part of the lives and livelihoods of the indigenous peoples and rural inhabitants of landscapes throughout the South American continent, from the cloud forests and puna of the Andean highlands to the coastal plains of Suriname, the Amazonian rainforest to the cold semi-deserts of the Patagonian steppe.[89]

Despite their location within what were formerly regarded as remote or "inaccessible" regions of the earth, the indigenous and pastoral peoples of remote areas in Asia and elsewhere are no longer effectively isolated from outside contacts and influences - most are now participants (willing or not) in the global network of trade and commerce, and rely heavily on trade goods and the marketing of plant and animal products for many [now] basic essential necessities of subsistence life e.g., tools, firearms, ammunition, clothing, fuels.[90] These peoples, along with their animals and crops, are also subject to a continuous rain of globally-circulating toxic pollutants: acid rain and heavy metals from industry and urban smog, pesticides from aerial spraying to reduce insect disease vectors and agricultural pests, and potential exposure to exotic disease pathogens from infected travellers, contaminated trade goods, and even potentially inadequately-treated aerosolized sewage or food debris from commercial or private aircraft used for international travel and commerce.

The current ease and rapidity of international transport of potential human and animal vectors of infectious diseases, coupled with the increasing virulence and variety of human-selected and human-engineered disease organisms, are setting the stage for disease epidemic scenarios that could equal or surpass those of any known historical precedent. We need to further develop the capability for early detection of diseased animals, both wild and domesticated, and enhance the availability of control technologies and containment facilities. Policy-makers and legislators must be made to recognize that the economic impacts of agricultural bioweapon diseases on non-agricultural sectors may far surpass the costs of direct losses in the agricultural sector. Expenditures on proactive disease prevention, containment and control infrastructure should ultimately pay for themselves many times over.

Our ability to understand and control the spread of diseases within and among human and animal populations is increasing, but is still

insufficient to counter the existing threats presented by bioweapons and a growing number of newly-recognized emerging infectious diseases like Ebola and Marburg fever, as well as the less devastating but more widespread potentially fatal diseases of humans and animals like the West Nile Virus, H5N1 Avian influenza and SARS. Interdisciplinary and international efforts to increase the surveillance and identification of disease pathogens, and to better understand the potential dynamics of disease transmission within and among human and animal populations in both industrialized- and developing-country settings, will greatly enhance our ability to combat the effects of bioweapons and emerging diseases on biotas and biodiversity. From the ecosystem health perspective, however, bioweapon diseases are only the most extreme example of the larger ecological problems associated with emerging infectious diseases of animals and plants, and the inadvertent and deliberate translocation of exotic and invasive species of plants, animals, invertebrates, and microbes by humans through global trade and transport networks.

Improved mechanisms for interagency and intergovernmental communication, cooperation, and collaboration will be necessary to effectively combat and control the threats of bioweapon disease outbreaks. Expenditures on disease prevention, containment and control infrastructure may prove expensive in the short-term, but collateral benefits for public health and food security will greatly increase the value of such investment to the national and global economy. Failures in the prevention and containment of bioweapon diseases and other exotic anthropogenic zoonotic diseases could result in the erosion of genetic diversity in wild and domesticated animal species, the extinction of endangered species, the extirpation of indigenous peoples, and the destruction of traditional human livelihoods and cultures.

Endnotes

1 Wilcox 2001.
2 Hughes 2001.
3 Lee 2001.
4 Henderson *et al.* 1999.
5 Daszak *et al.* 2000.
6 Woodford *et al.* 2002.
7 Noji 2001.
8 Henderson 1999.
9 Madden and van den Bosch 2002.
10 Christopher *et al.* 1997.
11 Leitenberg 2000.

12 Alibek and Handelman 2000.
13 Bozheyeva *et al.* 1999; Alibek and Handelman 2000.
14 See http://www.oie.int/eng/maladies/en_classification.htm).
15 Pandora's Box (a human creation story of Hellenic/Greek origin, perhaps derived from the same ancient oral traditions that generated the Semitic accounts of the creation of Adam and Eve and their expulsion from Eden): Zeus [the King of the gods] made the first Woman, and sent her to Prometheus and his brother Epimetheus to punish them for stealing fire from heaven to give to Man, and to punish Man for accepting the gift of divine fire. This first woman was called "Pandora" [literally translated, "the "all-giving one"]. She was made in heaven, every god contributing something of their own powers to enhance her abilities: Venus gave her beauty, Mercury persuasion, Apollo music, Mars gave her strength, Athene gave her wisdom, while the other gods each endowed her with one of their own special attributes or abilities. Thus equipped for her mission, Pandora was conveyed to earth and presented to Epimetheus as a gift from Zeus to reward his industry in the creation of Man. Epimetheus accepted her gladly, with thanks. Prometheus, however, was wary of Zeus's motives and urged his brother to be wary of this anomalous gift.
Now it happened that Epimetheus had in his house a sealed jar [i.e., amphora, a container or "box"] in which were kept certain noxious articles that he had discarded while he was designing and fitting Man for his new abode on Earth. Pandora was seized with an insatiable curiosity to know what things this special jar contained, and one fateful day she opened the Jar to see what it contained. From the open Jar escaped the multitude of ills that now plague hapless man – including Gout, Rheumatism, and Colic for his body, and Envy, Spite, and Revenge for his mind. Pandora hastened to replace the lid, but alas and alack! - the fell contents of the jar had already escaped to scatter themselves far and wide across the Earth. (Abstracted and amended from version at: http://www.bulfinch.org/fables/bulfinch.html)
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17 Bozheyeva *et al.* 1999, Alibek and Handelman 2000.
18 Dudley and Woodford 2002a.
19 Madden & van den Bosch 2002.
20 Henderson 1999.
21 Henderson *et al.* 1999.
22 Sauri *et al.* 2002.
23 Alibek and Handelman 2000.
24 Fenner *et al.* 1988.
25 Capps 1973.
26 Fenner *et al.* 1988.
27 Denevan 1992.
28 Kalter *et al.*1979; Woodford *et al.* 2002.
29 Sinclair 1979.
30 Dobson 1994.
31 Marks 1976.
32 Scott 2000.
33 Plowright 1982.
34 Roeder 2002.
35 Spinage 2003.
36 Sinclair and Norton-Griffiths 1979.
37 Alibek and Handelman 2000.
38 Dudley and Woodford 2002b.
39 Cheneau *et al.* 1999; Bengis *et al.* 2002.
40 FAO 2002.

41 Ruane 2000
42 FAO/UNEP 2000.
43 Ruane 2000, Toro *et al.* 2000.
44 FAO 2001.
45 Kennedy *et al.* 2000; Dudley and Woodford 2002b.
46 Daszak *et al.* 2000.
47 Ginsberg *et al.* 1995.
48 Roelke-Parker *et al.* 1996; Kelly 2001.
49 Dudley 2005.
50 Rappole *et al.* 2000.
51 Komar *et al.* 2003.
52 (254 of 3893 cases). http://www.cdc.gov/od/oc/media/wncount.htm
53 Dudley and Woodford 2002a.
54 Dudley 2005.
55 Iñigo-Elias and Ramos 1991.
56 Wilson *et al.* 2001.
57 USDA, Emergency Management Warning 15: Newcastle Disease; 8 January 2003.
58 USGS 2002.
59 CDC 2002.
60 Campos 1986; Thomsen and Brautigam 1991; Vickers 1991.
61 Dudley 2005.
62 de Vos 1990.
63 Alibek and Handelman 2000.
64 Dobson and May 1986; Singer *et al.* 2001.
65 Woodford *et al.* 2002.
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67 Leroy *et al.* 2004; Rouquet *et al.* 2005.
68 WHO http://www.who.int/csr/don/2003_02_26/en/
69 Mtembezi 2002.
70 Wheelis 1999.
71 Lawrence *et al.* 1980, Kobuch *et al.* 1990, Fenner 1993.
72 Gerges 1993, Roeder 1999.
73 Fenner 1993, Dudley *et al.* 2002.
74 Wilson *et al.* 2001.
75 PBS FRONTLINE 1998.
76 Kobuch *et al.* 1990, Pugh & Davies 1990.
77 http://www.promedmail.org/pls/promed/f?p=2400:1202:7554003387404127047::NO::F2400_P1202_CHECK_DISPLAY,F2400_P1202_PUB_MAIL_ID:X,14760
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81 Active 1998; Hensel and Morrow 1998.
82 Anderson 1998.
83 Active 1998; Hensel and Morrow 1998.
84 Mayr 1985.
85 Lamb 1974; Marks 1976.
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