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Review Article

Tackling the Problems of Emergence, Re-Emergence and Maintenance of Zoonoses by Wildlife Reservoirs in the Twenty First Century

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Abstract

Wildlife species have played a central role in the emergence, re-emergence and maintenance of major zoonotic diseases that pose serious threats to public health worldwide. These zoonoses are associated with high morbidity and mortality. The human immunodeficiency virus alone infects 33.3 million people worldwide, causing 1.8 million deaths and 1.9 million new cases in sub-Saharan Africa yearly. Human-wildlife contacts that result in zoonotic disease transmission include; the consumption of bushmeat, live wildlife trade, hunting and visits to game reserves. Despite the benefits derived from wildlife by several nations especially in the provision of animal protein requirements and the development of national economies, these contacts expose the public globally to the risk of zoonoses from wildlife reservoirs. Tackling these problems requires educating the public of the risk of zoonoses and the possible ways of contracting them from wildlife, vaccination of humans and wildlife against vaccinable zoonoses, wildlife disease surveillance, veterinary inspection of bushmeat before consumption, enforcement of regulations relating to wildlife disease management, fertility control and culling. Stake holders in the areas of public and animal health at local, national and international levels as well as non-governmental organizations should support in the funding of wildlife disease management programmes so as to curtail this menace.

Keywords: Tackling, problems, emergence, re-emergence, maintenance, zoonoses, wildlife reservoirs.

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Introduction

The emergence, re-emergence and maintenance of zoonoses by wildlife species call for concern and have even been described as national security threats (Brower and Chalk, 2003). Three quarter of all these emerging infectious diseases of humans are zoonotic, most of which are of wildlife origin with an increasing incidence since the 1940s (Tailor *et al*., 2001; Woolhouse and Gowtage-Sequeria, 2005; Jones *et al*., 2008). Zoonoses can be transmitted from wildlife species to humans either directly through skin contact with infected animals (eg. tularemia), bite of infected animals (eg. rabies), aerosol (eg. Hantavirus infection) or indirectly by way of food and water contamination (salmonellosis, leptospirosis) or through insect vectors with examples including human African trypanosomosis, rift valley fever, equine encephalitis, ehrlichiosis among several others (Kruse *et al*., 2004).

Several very important zoonoses have emerged or re-emerged from wild life species. For instance HIV was transferred from primates to humans probably during hunting (Barre-Sinoussi, 1996), Ebola virus outbreaks have resulted from the handling of gorilla or chimpanzee carcasses (LeRoy *et al*., 2004) and SARS is said to have originated from small wild carnivores (Peiris *et al*., 2004). Others include the highly pathogenic avian influenza that originated from wild birds (WHO, 2005) as well as tularaemia and borreliosis which were both transmitted from rodents to humans (Kruse *et al*., 2004).

The role of wildlife in the emergence and maintenance of zoonoses has long been established (Rhyan and Spraker, 2010). This can be influenced by factors such as; the diversity of wildlife microbes in a region (Morse, 1993), effects of environmental changes on the prevalence of pathogens and the frequency of human contact with wildlife reservoirs (Wolfe *et al*., 2005). These human-wildlife contacts may result from the encroachment of humans into wildlife habitats for reasons such as agriculture (Field and Epstein, 2011), human settlement and wildlife park visits (Cleaveland *et al*., 2007; Craft *et al*., 2009) as well as hunting and trading of live wildlife species (Barre-Sinoussi, 1996; Chipman *et al*., 2008).

The trade of wildlife species either for consumption or companionship has increased the potential for the spread of zoonotic diseases which pose serious public health risk (Marano *et al*., 2007). The high demand for bushmeat in many parts of the world, especially in Asia and Africa is a major source of emerging zoonoses. This is evident by the outbreaks of Ebola virus and highly pathogenic avian influenza in Western Africa and Asia respectively (Chomel and Marano, 2009). The threats caused by these diseases to human and animal populations, food security and safety, environmental diversity and international trade of live animals and animal products are of major concern (Karshima, 2012). This review underscores the burdens of some zoonoses of wildlife origin, means of contact between human and wildlife species and the possible strategies for prevention and control of zoonoses arising from wildlife.

Historical burden of some zoonoses of wildlife origin

Human Immunodeficiency Virus (HIV)

The first reported cases of AIDS were being identified immediately after the declaration of small pox eradication by World Health Organization in 1980 (CDC 1981). Within 26 years of emergence HIV/AIDS has caused an estimated 65 million infections resulting in 25 million deaths (UNAIDS, 2006). Although blood transfusion, indiscriminate and unprotected sex as well as drug addiction facilitated the spread, the simplest and plausible explanation for the emergence of the virus appears to be exposure to animal blood and secretions through hunting and processing of primates, or the subsequent consumption of raw or undercooked bushmeat (Barre-Sinoussi, 1996; Sharp *et al*., 2001). About 106 of 573 blood samples obtained from freshly butchered primates in bushmeat markets showed evidence of Simian Immunodeficiency Virus (SIV) in which the HIV is believed to have evolved (Peeters *et al*., 2002).

It was estimated that about 33.3 million people are living with HIV/AIDS globally with annual deaths amounting to 1.8 million (UNAIDS, 2010).

Of this global burden sub-Saharan Africa alone represents 68.8% (22.9 million), while North America as well as West and Central Europe represents 4.5% (1.5 million) and 2.5% (820,000) respectively (UNAIDS, 2010). In sub-Saharan Africa alone, HIV/AIDS was estimated to cause 1.2 million deaths in 2010 and render about 14.8 million children orphans since its emergence (UNAIDS, 2010). Also about 1.9 million new cases were reported in sub-Saharan Africa in the year 2010.

Ebola haemorrhagic fever (EHF)

Ebola viruses pose serious threats to both public and wildlife health in the Congo and Nile basins. The first reported outbreaks emerged in 1976 in the Democratic Republic of Congo (DRC) and Sudan between three months interval (June and September respectively). However it was established that the two outbreaks were caused by two species named *Zaire ebolavirus* (ZEBOV) and *Sudan ebolavirus* (SEBOV) which were antigenically and biologically distinct (Muyembe-Tamfum *et al*., 2012). The outbreaks in Sudan and DRC in 1976 recorded 53% (151/284) and 88% (280/318) mortality rates respectively (WHO, 1978a, b). Again in 1979, a small outbreak emerged in Nzara and Maridi both in Sudan with mortality rate of 64% (22/34).

After a break of 13 years of the infection, EHF re-emerged and this time spread to other parts of Africa. The outbreak in Cote d' Ivoire was reported in 1994 and was believed to have originated from a chimpanzee. This outbreak was caused by a different specie of Ebola virus which was named *Cote d' Ivoire ebolavirus* (Le Guenno *et al*., 1995). This was followed by the outbreaks in Gabon in 1994, 1996, 1997 and 2001-2002 which were caused by *Zaire ebolavirus* (ZEBOV). These outbreaks were associated with the handling of a sick gorilla killed during hunting (George-Courbot *et al*., 1997a, b; Leroy *et al*., 2002).

Other EHF outbreaks were ZEBOV that occurred in the DRC in 1995 with 79.4% (250/315) mortality rate (Khan *et al*., 1999), and those that were reported in 2007 and 2008 in the DRC with mortality rates of 70.0% (187/264) and 43.8% (14/32) respectively (Leroy *et al*., 2011; Muyembe-Tamfum *et al*., 2012). Furthermore outbreaks were reported in Uganda in 2000 and 2007 with mortality rates of 52% (224/425), and 26% (30/116) respectively (Lamunu *et al*., 2004; Towner *et al*., 2008). An isolated case of EHF caused by SEBOV was reported in Uganda in 2011 (WHO, 2011). Another outbreak with mortality rate of 41.2% (7/17) was reported in Sudan in 2004 (Onyango *et al*., 2007).

Severe Acute Respiratory Syndrome (SARS)

Severe Acute Respiratory Syndrome was first reported in 2002 in the Guangdong Province of China in cases that initially presented as atypical pneumonia (Xu *et al*., 2004; Rosling and Rosling, 2003). This was followed by sudden increased in cases of pneumonia in the surrounding areas involving several hospital workers with several unexpected deaths (Zhong *et al*., 2003). Months after the initial case of this atypical pneumonia, a physician from Guangdong travelled to Hong Kong, infecting up to 16 others during a brief hotel stay. This triggered a global pandemic with outbreaks in Hong Kong, Singapore, Vietnam, and Canada (Ksiazek *et al*., 2003; Poon *et al*., 2004). Between the end of 2002 and early 2003 the epidemic had already reached its peak affecting more than 25 countries in five continents. Although human to human transmission was already contained by July, 2003, there was estimated 9.7% (774/8000) mortality rate (WHO, 2003; Peiris *et al.*, 2004).

The largest numbers of SARS cases occurred in mainland China, Hong Kong, Taiwan, and Canada (where a significant outbreak occurred in the city of Toronto). In the United States, though no death was recorded as a result of SARS, there were 29 cases of probable SARS, all of which were linked to preceding international travels to endemic areas (Peck *et al*., 2004, Isakbaeva *et al*., 2004). Four cases were reported in Guangdong in late 2003; three separate laboratory-related incidents were reported in Singapore, Taiwan, and China, one of which resulted in a small contained community outbreak (Fleck, 2004). It was observed that among all health care workers, staff of the emergency department had highest attack rate of 11.9% (38/322) in comparison with staff of the Intensive Care Unit (Li *et al*., 2003). Another epidemiological study from Toronto found that transmission of SARS to staff of the emergency department who had contact with SARS patients ranged from 0% to 22% with a calculated attack rate of 13.6% per 1000 nursing hours, exceeding that found in the Emergency Care Unit (Varia *et al*., 2003).

Influenza viruses

Globally, influenza epidemics results into 3-5 million cases of severe illness and approximately 250,000 to 500,000 deaths annually. Over 100,000 hospitalizations and about 40,000 deaths among the elderly and young occur yearly in the United State as a result of influenza (WHO, 2003).

Three influenza pandemics have emerged during the past century. Between 1881 and 1919, the Spanish flu emerged claiming about 40 million lives globally and 650,000 in the United State alone. The Asian flu emerged between 1957 and 1958 causing 34,000 deaths in the United State alone and 70,000 deaths also resulted from Hong Kong flu between 1968 and 1969 (Cox and Subbarao, 2000).

The avian strain A of influenza virus (H5N1) was the first avian virus to have been transmitted directly from birds to humans (CDC, 1997). This virus was first reported in several Asian nations (Manto, 2005; Stohr, 2005). This highly virulent strain of influenza has caused nearly 200 reported deaths globally (Ungchusak *et al*., 2005).

Lassa Hemorrhagic Fever (LHF)

Lassa hemorrhagic fever is an acute viral hemorrhagic fever caused by the Lassa virus. It was first described in 1969 in the town of Lassa, in Borno State, Nigeria (Frame *et al.*, 1970).The Lassa fever virus is a member of the arenaviridae virus family similar to Ebola (Ogbu *et al.,* 2007). Clinical cases of the disease were known for over a decade but were not connected with a viral pathogen. The infection is endemic in West African countries, and causes 300,000–500,000 cases with approximately 5,000 deaths annually (Ogbu *et al.,* 2007). Outbreaks of the disease have been observed in Nigeria, Liberia, Sierra Leone, Guinea, and the Central African Republic, but it is believed that human infections also exist in Democratic Republic of the Congo, Mali, and Senegal. The primary animal host of the Lassa virus is the Natal Multimammate Mouse (*Mastomys natalensis*), an animal indigenous to most of Sub-Saharan Africa (McCormic *et al*., 1987).

The virus is probably transmitted by contact with the faeces or urine of animals accessing grain stores in residences (McCormic *et al*., 1987). Given its high rate of incidence, Lassa fever has become a major problem in the African region (McCormic *et al*., 1987. The first reported deaths due to LHF were in 1969 when the disease killed two missionary nurses in Lassa, Nigeria (Frame *et al*., 1970). The disease is devastating causing thousand of human deaths in West Africa annually (Branco *et al.*, 2011b). About 34 years following first report of LHF, the public health crisis associated with the disease is yet to be determined due to lack of infrastructure and rapid field diagnostic techniques (Branco *et al.*, 2011a). About 16.5% (73/441) mortality rate was reported in Sierra Leone (McCormic *et al*., 1987) while 65% (22/34) was reported in Nigeria (Fisher *et al*., 1995).

Monkey pox

Monkeypox which is believed to have originated from nonhuman primates occurred between 1958 and 1968 (Arita and Henderson, 1968; Arita *et al*., 1972; Jezek and Fenner, 1988). Nine outbreaks were reported in animals between these ten years with six restricted to Asian monkeys while the other three outbreaks involved a mixture of animals from Asia, Africa and South America (Arita and Henderson, 1968; Arita *et al*., 1972; Jezek and Fenner, 1988).

Human monkeypox investigations began in the tropical rainforest areas of some West and Central African countries between 1970 and 1979 just about the time small pox eradication was declared by the World Health Organisation (Breman, 2000). During these nine years, a total of 54 human monkeypox cases were confirmed in the forested areas of Western and Central Africa, with 84% (44/54) of these cases been in the Democratic Republic of Congo (Foster *et al*., 1972; Jezek and Fenner, 1988; Ladnyi *et al*., 1972; Lourie *et al*., 1972).

Majority of human cases resulted from contact with diseased animals with only five instances of human-human transmission (Foster *et al*., 1972). Between 1980 and 1986, another 350 cases were reported with 98% (342/350) been from the forested areas of the DRC. Also between 1970 and 1986, a total of 1,2,3,4 and 6 human monkeypox cases were reported in the forested areas of Cameroon, Cote d'Ivoire, Nigeria, Liberia and Central African Republic respectively (Breman, 2000). Case fatality rates in the DRC were approximately 10% in non-vaccinated individuals (Jezek and Fenner, 1988).

The disease was also reported in 37 persons who presented febrile rash illness in 2003 in the United State of America. This human outbreak was reported to have originated from monkeypox infected West African rodents imported from Ghana and this was the first report of human monkeypox outside Africa (CDC, 2003).

Rabies

Rabies is a violent viral zoonosis that poses serious global public health threats particularly in Asia and Africa. The name rabies originated about 3000 BC from the word rabha which means violence and the disease is known for more than 4300 years (Takayama, 2005; 2008).

The existence of wildlife reservoirs of rabies is well documented. Rabies virus has been documented from red and arctic foxes (Rupprecht *et al*., 1991), gray fox (Smith and Baer, 1988), coyote (Smith, 1989; 1996), raccoon (Jenkins and Winkler, 1987), skunk (Parker, 1975) and bats (Smith, 1996). The disease causes 55,000 annual mortalities with 56% (308,000/55,000) and 44% (24,200/55,000) occurring in Asia and Africa respectively. It is also estimated that over 99% of human cases of rabies are as a result of bite of domestic dogs, probably due to their increased number and poor handling in developing countries (Adaba *et al*., 2004). With an annual death of 55,000 in Asia and Africa, rabies is estimated to have a total Daily Adjusted Life Years score of 1.7 million and a global financial burden of 583 million US dollars (Knobel *et al*., 2005).

Human-wildlife interactions

Several factors including the search for improved economy, animal protein and settlement have brought man in contact with wildlife species by invading their habitats thus exposing humans to the risk of zoonoses from wildlife reservoirs. Some of the common means of contact between humans and wildlife include;

Live wildlife trade

Live wildlife trade in the context of this review refers to the domestic and international trade in wildlife species for companionship, research, food and processing of secondary products like clothing. This trade cannot be easily quantified as it occurs both legally and illegally on the local and international levels. In sub-Saharan Africa, wildlife is believed to contribute significantly to the economies of most countries with an estimated worth of 7 million US dollars and an annual growth rate of 5% (Kock *et al*., 2002). For instance, in Kenya wildlife contributes up to 30% of the country's foreign exchange earnings through tourism (Kock *et al*., 2002).

It is estimated that about 40,000, 4 million, 640,000 and 350 million live primates, birds, reptiles and tropical fish respectively are traded globally each year (Karesh *et al*., 2005). Approximately 38 million live mammals, birds, amphibians and reptiles were legally imported into the United State of America from 163 different countries between 2000 and 2004 (Jenkins *et al*., 2007; Marano *et al*., 2007). Also in 2005 alone, about 210 million animals including 203 million fish, 5.1 million amphibians, 1.3 million reptiles, 259,000 birds and 87,991 mammals were imported live into the United State of America for zoos, exhibition, food, research, game ranches and companionship (Chomel and Marano, 2009).

On the other hand, global trafficking of wildlife also contributes significantly to national economies with an estimated annual worth ranging between 10 to 20 billion US dollars annually (IAR, 2007). In Vietnam alone, illegal wildlife trade is valued for 20 million US dollars annually (Bell *et al*., 2004).

The benefits of live wildlife trade to national economies are numerous; however these trades pose serious public health threats in the area of emergence re-emergence and maintenance of zoonoses. For instance, a parrot imported into the United Kingdom in October 2005 died of avian influenza in a quarantine section (BBC, 2005). Also Ebola virus was imported into the United State in monkeys destined for research (Jahrling *et al*., 1990). The first outbreak of human monkeypox outside Africa which occurred in the United State in 2003 was linked to monkeypox infected West African rodents imported from Ghana (CDC, 2003). All these instances indicate the global public health risk associated with the importation of live wildlife species.

Bushmeat trade and consumption

Bushmeat is an African name for the meat of wild animals which include rats, porcupine, grass cutter, monkeys, great apes, elephants, turtles, snakes and crocodiles. It is a major source of protein for people in consistence economies. The consumption of bushmeat by humans has been in practice for millions of years (Boesch, 1994). It is estimated that about 4.5 million tons of bushmeat are consumed in the Congo basin alone each year (Fa *et al*., 2002).

Reports show that 67,000 to 164,000 tons of bushmeat are consumed in the Amazon annually (POST, 2005). In Sarawak, Malaysia an estimated 2.6 million wild animals are shot and 23,500 tons of wild meat are consumed each year (Sohdi *et al*., 2004), while in Vinh City, Nghe An Province Vietnam, 600 kg of Civet meat is consumed in four restaurants every month (Bell *et al*., 2004). International trade of bushmeat to cities like London has also been reported (Kirby, 2004). The illegal trade of bushmeat into the United Kingdom from non-EU countries in 2004 alone amounted to 4,000 to 29,000 tons (POST, 2005).

The yearly value of bushmeat is estimated at 117 million and 42 million US dollars in the Ivory Cost and Liberia respectively (Robinson and Bodmer, 1999). In the Ivory Coast, the Gross Domestic Product realized from bushmeat alone was higher than that obtained from domestic beef production, tropical wood exports, bananas and pineapples put together (Bassett, 2005). The risk of contracting zoonoses from the consumption of wildlife meat has also been established. For instance, the human immunodeficiency virus is thought to have been transferred to humans through the contact with the blood and secretions from primates as a result of processing and subsequent consumption of raw or undercooked meat from primates (Barre-Sinoussi, 1996; Sharp *et al*., 2001).

Fig. 1: A man with a companion wild bird *Milvus migrans migrans* commonly called black kite. This can be a possible source of zoonosis like avian influenza.

Fig. 2: A man with a companion monkey *Cercophitecus pygerythrus* commonly called vervet monkey. This can be a possible source of zoonosis like monkey pox.

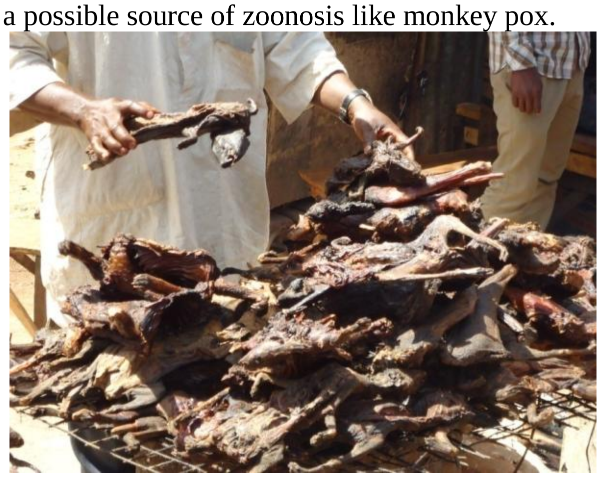

Fig. 3: A bushmeat mini market in Jos, Nigeria. The processing and consumption of these bushmeats can expose humans to zoonoses if not adequately prepared.

Other endemic and neglected zoonoses such as cysticercosis, salmonellosis and brucellosis that are maintained in wildlife species can also be transmitted to humans through the consumption of raw or undercooked bushmeat.

Hunting and processing of wildlife meat

Hunting is estimated to contribute up to 80% of the protein consumed by forest-dwelling families in the Congo Basin (Koppert *et al*., 1993). It is recently commercialized leading to dramatic increase in bushmeat production worldwide. Hunting exposes humans to insect vectors thereby increasing the risk of vector-borne zoonoses such as human African trypanosomosis which is transmitted by *Glossina* species.

Human contacts with a wide range of wildlife tissues and fluids during hunting and butchering of wildlife expose humans to risk of zoonoses (Wolfe *et al*., 2000). Wildlife hunting has been associated with the emergence and re-emergence of cutaneous diseases such as contagious pustular dermatitis (Wolfe *et al*., 2000) and monkeypox which is associated with the preparation and consumption of infected rodents (Pattyn, 2000). It is shown that as much as 30 different species of primates are hunted and processed in Africa posing the risk of cross-species disease transmission. For instance, the hunting of colobus monkeys was implicated in a localized epidemic of human monkeypox that persisted for four generations of human-human transmission (Jezek *et al*., 1986). The human outbreaks of Ebola haemorrhagic fever have been traced to exposure to the dead bodies of infected chimpanzees (WHO, 1996) and gorillas (WHO, 2003) hunted for food.

Visits to game reserves

Game reserve visits can also expose tourists to zoonotic diseases especially those transmissible through vectors and aerosol route. Game reserves are natural habitats for tsetse flies and other insect vectors that can transmit vector-borne zoonotic diseases between wildlife species and tourists visiting the reserves. For instance, human African trypanosomosis (Sleeping sickness) was reported in a young American tourist who visited Tropical Africa (Conway-Klaaseen *et al*., 2002) and travellers who visited Tanzania National park (Jelinek *et al*., 2002).

Tackling the problems of zoonotic disease emergence re-emergence and maintenance by wildlife

The prevention and control of zoonoses associated with wildlife reservoirs might not be a common task for reasons related to undefined targeted population (Wobeser, 2007), potential number and unpredictability of the agents involved, the geographic area and terrain to be covered, difficulty of capturing live animals for sampling and finding of un-scavenged dead animals on the field (Stallknecht, 2007). However, the problem of zoonotic disease emergence re-emergence and maintenance by wildlife reservoirs can be tackled through some of the following strategies:

Essential Veterinary Education

Wildlife and Public Health Veterinarians at the local, national and international levels should educate the public on the risk of contracting zoonoses from wildlife species through companionship, consumption, hunting or trading of such wild animals. The public can also be educated on the need for receiving immunization against vaccinable diseases that are transmissible between humans and wildlife species such as rabies. Other necessary information that must get to members of the public include the risk of contracting zoonoses through the consumption of raw or undercooked wild animal products and the need to use protective wears such as hand gloves during the handling and processing of meat from wildlife species. Hunters should also be encouraged to present bushmeat for veterinary inspection before forwarding for human consumption. More so, it is very essential to incorporate courses that deal in detailed with wildlife diseases and their role in the emergence of zoonotic diseases into the curriculum of Veterinary schools. Public Health Veterinarians should again educate immunocompromised individuals of the increased risk of associating with wildlife species for companionship and even consumption if not properly prepared.

Wildlife disease surveillance

A successful surveillance of zoonoses among wildlife reservoirs have a broader scope targeting generally emerging zoonoses and should not be restricted to a particular disease as is seen in some public health programmes like the rabies response, West Nile Virus detection and the highly pathogenic avian influenza detection which were particularly specific for rabies, West Nile Virus and Highly pathogenic avian influenza respectively. Surveillance for zoonoses among wildlife species can be based on case-finding by members of the public or staff of the environmental agencies in which case it is termed passive surveillance. The effectiveness of passive surveillance depends on the population size engaged in identifying cases of diseases and deaths among wildlife species and their ability to forward the right samples to the laboratory for diagnosis. The detection of death carcasses can be done using trained dogs which was observed to be more effective than humans (Homan *et al*., 2001).

In active surveillance of wildlife diseases, data collection is intended to derive information about specific agents or diseases and is based on a cross-sectional study design, and targets antibodies to disease agents or the etiological agents themselves. Effective surveillance of zoonoses in wildlife reservoirs requires the involvement of National and International public and animal health organizations such as OIE, FAO, WHO in equipping and standardizing diagnostic laboratories and training of public health personnel to take up the responsibility. The success of wildlife disease surveillance in zoonoses prevention and control can be seen in the eradication of screwworm in the United State (Wyss, 2000; Baumhover, 2002).

The establishment of National programmes targeting the prevention and control of zoonoses in wildlife reservoirs will also go a long way in the management of wildlife diseases. For example, programmes like National Wildlife Management Programme (NWMP), National Wildlife Research Centre (NWRC) and the Wildlife Services of the United State Department of Agriculture are all involved in wildlife disease surveillance and monitoring (Belant and Deese, 2010).

Vaccination of wildlife species against zoonoses

Vaccination is a disease prevention strategy which is believed to be better and cheaper than cure. Curtailing zoonotic disease transmission to humans through wildlife vaccination will help in the prevention and control of zoonoses in wildlife reservoirs. Wildlife vaccination against zoonoses should be encouraged considering the cost effectiveness of animal intervention in the control of zoonoses. For instance, it was observed that it is 50 times cheaper to employ animal intervention in the control of rabies in Nigeria through the vaccination of dogs than administration of both pre and post-exposure Anti-Rabies Vaccine in humans (Karshima, 2012).

Unsuccessful attempts were made in the vaccination of wildlife as seen in the use of firing vaccine-filled polymer bullets from air guns to vaccinate elk on feeding grounds against brucellosis probably due to the poor efficacy of the vaccine in elk (Cheville *et al.*, 1998). However, the control of rabies among wildlife in Europe and the United State of America was successful through the use of remote rabies vaccine (Rhyan and Spraker, 2010). Also strategically placed vaccinia-based oral vaccine controlled the spread of rabies in some wild canid population (Slate *et al.*, 2005). The production of water soluble vaccines for different zoonoses of wildlife origins that can be administered in drinking water and placed at strategic places where wildlife species visit to drink water will go a long way in tackling the problem of zoonoses from wildlife reservoirs. For instance, vaccination of wildlife species against diseases can be achieved by constructing artificial watering areas such as shallow water reservoirs in the habitats of these animals and then administering water soluble oral vaccines into the water. These animals will naturally drink such waters in their environment instead of going long distances in search of water. This will help to provide herd immunity where 70% or more of the animals in such herds will be immune and subsequent exposures between these wildlife reservoirs will be between unsusceptible animals.

Immunization of humans against zoonoses of wildlife origin

It is important to enact vaccination policies in all countries and follow up to ensure that the public comply with these policies. Immunizing the population at risk against vaccinable zoonotic diseases will go a long way in protecting them against these diseases even when they have contact with infected wildlife. For instance rabies is now endemic in many developing countries and therefore government at all levels must ensure that the public is protected through the use of pre-exposure rabies vaccination and the antibody titre checked as it is recommended (Trevejo, 2000; CDC, 2008). Provisions should also be made for post-exposure for victims of rabies arising from both wildlife or domesticated animals. Other vaccinations that should be made available for the public include tetanus vaccination which is recommended every 10 years (CDC, 2006) and influenza vaccines (CDC, 2006; Gray and Baker, 2007).

Culling of wildlife reservoirs

Culling refers to depopulation and usually reduces the size of the total population. However, it can be used to reduce the number of infected animals only. Although depopulation is the extreme form of culling and is been agitated all over the world as destabilising biodiversity, it still remains the fastest means of breaking disease transmission and reducing the population of wildlife species incubating and shedding zoonotic agents in the environment. The effectiveness of culling in the control of wildlife diseases has been established. For instance the depopulation of feral water buffalos controlled bovine tuberculosis (zoonotic tuberculosis) in Australia (Corner, 2006). With the application of about 50,000 strychnine baits in Alberta, Canada, a total of 50,000 target foxes, 35,000 coyotes, 4,200 wolves, 7,500 lynx and 1,850 bears were killed in an attempt to curtail the spread of rabies (Ballantyne and O'Donoghue, 1954).

Veterinary inspection of bushmeat

The role of veterinary meat inspection which targets public health can never be over emphasized in the prevention and control of zoonoses from wildlife reservoirs. This if properly done is believed to be able to protect 10% of the human population that contract food-borne zoonoses yearly (Kaferstein and Abdussalam, 1999; Schlundt *et al*., 2004). Veterinary inspection is important in the control of diseases such as cysticercosis, hydatidosis, trichinellosis and bovine tuberculosis (zoonotic tuberculosis) among others.

The government can enforce veterinary inspection of bushmeat by enacting laws that will compel all hunters to present meat hunted from wildlife species for veterinary inspection before forwarding for human consumption. In support of these policies, the government should build slaughter houses in rural settlements where wildlife species are hunted for food so that carcasses from such animals will be subjected to meat inspection. In addition, veterinarians should be trained in wildlife disease management and engaged to take up these responsibilities.

Enforcement of regulations

Regulations concerned with the importation and movements of wildlife species at the local, national and international levels should be reinforced. For instance imported wildlife species for companionship, food and recreation must be examined and quarantine for the appropriate time required by veterinarians at the National borders before been allowed in to a country. There should be strict adherence to the issuance of certificate of freedom from zoonoses and other diseases for all importing and exporting wildlife species and these animals should be subjected to inspection at the various national and international control posts for evidence of diseases or freedom from same.

Fertility control

The operational principle of fertility control is similar as that of culling, and is based on the reduction of population size below a threshold where infection can be maintained (Killian *et al*., 2007). This involves administering an immunocontraceptive vaccine that renders wildlife infertile thereby reducing population growth rate. Fertility control has the theoretical potential to reduce population size. However, the development of such a vaccine, its delivery methods and the demographic and epidemiological consequences are under investigation before its widespread application (Killian *et al*., 2007).

Conclusion

The human benefits of animal intervention in the control of zoonoses are enormous (Zinsstag *et al.*, 2007) and has been shown to be 50 times cheaper considering the case of rabies control in Nigeria (Karshima, 2012). However, intervention in wildlife species is associated with several challenges including undefined population size, unpredictability of the disease agents involved, the geographic area and terrain to cover, difficulty in capturing wildlife species and detection of dead animals un-scavenged among others. An ideal prevention and control programme for zoonoses in wildlife reservoirs must overcome these challenges.

Diseases of wildlife origin such as the HIV/AIDS, severe acute respiratory syndrome, ebola haemorrhagic fever, the highly pathogenic avian influenza among others have pose serious public health threads over the years. To protect the human population worldwide from these threats, wildlife disease control strategies such as the vaccination of humans and wildlife species against vaccinable zoonotic diseases, enforcement of regulations governing wildlife disease management, provision of essential veterinary education that will equip the public towards self defense, the inspection of bushmeat before consumption, fertility control among wildlife species and culling where necessary need to be employed.

As seen in the developed countries, developing countries must also institute programmes that will be responsible for the monitoring of zoonoses among wildlife species in their countries. International organizations responsible for public and animal health like the WHO, OIE and FAO should support developing countries in the provision of standardized laboratories as well as training of staff to help curtail the transmission of zoonoses between wildlife and humans.

The veterinary inspection of bushmeat may not be easy considering the un-organized nature of bushmeat hunting and trading in other parts of the world. However, if the public is educated of the risk associated with the consumption of infected bushmeat, they are likely to present such hunted meats for inspection. This is necessary because it will protect the public against food-borne zoonoses associated with wildlife species like zoonotic tuberculosis caused by *Mycobacterium bovis* and cysticercosis which is believed to be associated with epilepsy in sub-Saharan Africa as a result of the invasion of the brain and spinal cord of infected humans by the cestode larva *Cysticerci* (Diop *et al*., 2003).

Sustainable control of vectors including *Glossina*, mosquitoes and ticks will curtail the spread of vector-borne zoonoses like human African trypanosomosis. Un-functional vector control programmes should be reinstated. The control of zoonoses among wildlife reservoirs requires funds and therefore stake holders at the local, national and international levels as well as non-governmental organizations should take up the responsibility of sponsoring research programmes targeting wildlife disease management.

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