Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review

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Dates:
Received: 29 Feb. 2012
Accepted: 20 Aug. 2012
Published: 05 Dec. 2012

How to cite this article:
Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422

With on-going changes in land use practices from conventional livestock farming to commercial, wildlife-based activities, the interface or interaction between livestock and wildlife is increasing. As part of the wildlife-based activities of ecotourism, breeding and hunting, game farmers are also exploring the utilisation of meat from hunted or harvested game. The expanding interface or increased interaction between livestock and wildlife increases the risk of disease incidence and the emergence of new diseases or the re-emergence of previously diagnosed diseases. The risk is not only related to domestic and wild animal health, but also to the occupational hazards that it poses to animal handlers and the consumers of game meat. This review endeavours to highlight the role that game plays in the spreading of zoonotic diseases to other animals and humans. Examples of zoonotic diseases that have occurred in wild animals in the past, their relevance and risk have been summarised and should function as a quick reference guide for wildlife veterinarians, ecologists, farmers, hunters, slaughter staff, processors and public health professionals.

Introduction

The progressive expansion of game ranching as an extensive form of game farming on developed (fenced) land in southern Africa has resulted in ranching with endangered and/or rare species which can to a greater or lesser extent, be found in free community with livestock. In many parts of the world, farmers are changing from conventional livestock farming to commercial, wildlife-based activities such as ecotourism, which usually requires a wide diversity of frequently translocated species and adequate populations for tourist viewing (Bengis, Kock & Fisher 2002). With game becoming more valuable and therefore stocked at higher densities on smaller properties, disease prevention has become a very important aspect of game ranch management (Bester & Penzhorn 2002). A survey amongst South African game farmers revealed that 34.3% of these farmers are farming with both domestic and game animals (Bekker 2011). Skinner (1970) expressed concern regarding the dangers that game poses to domestic livestock by acting as reservoir hosts of pathogens of livestock which can cause epizootic disease and also that the handling and management of wild animals in relation to disease control is difficult. In support of this, Bengis *et al*. (2004) were of opinion that the abovementioned situations will probably enhance and intensify the wildlife-livestock interface and that the potential for 'cross-over' of diseases will increase. The cross-over of epizootic outbreaks represents a serious threat both to wildlife and, via reverse spill-over ('spill-back'), to sympatric populations of susceptible domesticated animals (Daszak, Cunningham & Hyatt 2000). Bengis *et al*. (2002) also indicated that foreign animal diseases cycling in livestock may cross the interface and infect wildlife. Wildlife therefore plays an important role in the spreading of transmissible animal diseases. In the United States, the presence of brucellosis amongst elk and bison in the Yellowstone National Park is considered a potential threat to domestic animals grazing in the park (Daszak *et al*. 2000). Godfroid (2002) was of the opinion that the development of the game farming industry has contributed to the re-emergence of brucellosis. Diseases such as malignant catarrhal fever (MCF) in wild herbivore species often show few clinical signs, but the disease is often deadly to cattle. According to Li *et al*. (1996), the viruses responsible for MCF are an important obstacle to the propagation of endangered ruminant species in the wild, in captivity, or on game farms. Although the Office Internationale des Epizooties (OIE) has declared that rinderpest has now been eradicated from the surface of the earth and that all 198 countries and territories in the world with rinderpest-susceptible animals are free of the disease (Food and Agricultural Organization [FAO] 2011), Gortázar *et al*. (2007) have pointed out that true multihost diseases that are regarded as eradicated are the worst, because a single spill-over from wildlife to livestock may have severe consequences for health and the economy. Rinderpest, for example, was eradicated in Nigeria in 1974 after the JP15 campaign, but was reintroduced between 1980 and 1983 into two states of Nigeria from infected cattle to wildlife,

and this resulted in the loss of an estimated one million cattle and numbers of wildlife, of which 207 buffalo, 20 warthog, eight waterbuck and two bushbuck carcasses were recovered (Shanthikumar & Atilola 1990). Other examples of multihost diseases include bovine TB (Michel *et al*. 2006; Phillips *et al*. 2003), foot and mouth disease (Scoones *et al*. 2010) and avian influenza (Alexander 2000; Gauthier-Clerc, Lebarbenchon & Thomas 2007).

Regarding zoonotic diseases, Cleaveland, Laurenson and Taylor (2001) then already indicated that 61% (868) of the 1415 species of infectious organisms known to be pathogenic to humans were of zoonotic nature. Some of these diseases can be transmitted through the consumption of animal-infected material or through the handling of such material (occupational disease). For the purpose of this review, human tuberculosis as a result of *Mycobacterium bovis* is briefly discussed. Several publications have already appeared on the prevalence of bovine tuberculosis in African wildlife and elsewhere in the world (e.g. Ayele *et al*. 2004; Michel 2002; Michel *et al*. 2006; Parra *et al*. 2006; Zieger *et al*. 1998). It was estimated by the World Health Organization (WHO) that *M. bovis* is the causative bacterium in 3% of all tuberculosis cases (WHO 1994a). Although high priority is placed on the meat inspection function at formally registered abattoirs to identify and remove carcasses with lesions of *M. bovis* from the food supply chain, asymptomatic animals or localised lesions could pass through the inspection system unnoticed (Van der Merwe *et al*. 2009). Poor and rural communities, furthermore, often obtain meat from uncontrolled and unregistered slaughter facilities where there is no meat inspection. Regarding game abattoirs, Bekker (2011) showed that in South Africa there are only a few registered game abattoirs, which are mostly used for export purposes, and that the real number and location of game slaughter facilities located on game farms are unknown to the relevant authorities and that almost no meat inspection is done on game farms. According to Cosivi *et al*. (1998), the intake of uninspected game meat may increase the risk of contracting tuberculosis. A number of authors such as Cosivi *et al*. (1995), Cosivi *et al*. (1998), De la Rua-Domenech (2006) and Thoen, Lobue and De Kantor (2006) have reported on human tuberculosis due to *M. bovis* globally. Some other examples of zoonotic diseases contracted by humans include a cutaneous anthrax outbreak that occurred in rural Paraguay through touching the meat of a sick cow (Harrison *et al*. 1989); an anthrax occurrence in Mashonaland East province of Zimbabwe due to handling, eating and drinking products of an infected animal (Mwenye, Siziya & Peterson 1996); brucellosis contracted by workers in meat packing plants (Taylor & Perdue 1989; White *et al*. 1974) and eating of caribou meat (Chan, Baxter & Wenman 1989); human trichinellosis which occurred in northern Italy after eating raw horse meat (Pozio *et al*. 1988); and the 2010 outbreak of Rift Valley fever (RVF) in South Africa where 172 cases and 15 human deaths after direct contact with RVF-infected livestock were reported by the national health department in South Africa (WHO 2010).

Pavlin, Schloegel and Daszak (2009) indicated that the simplest way to minimise the risk of zoonotic disease is the reduction of opportunities for transmission of diseases from wildlife to humans. Although not clear for the neighbouring countries of South Africa, the survey amongst South African game farmers by Bekker (2011) indicated, however, that 41% of farmers with mixed farming systems have no control measures to prevent animal interaction in order to prevent disease spreading between game and domestic animals. Furthermore, specific gaps have been identified in game farming practices insofar as the establishment of written health plans, routine health inspections, screening for zoonotic diseases, provision of quarantine camps and record keeping of health and withdrawal periods as suggested by the GlobalGAP integrated farm assurance standard (GlobalGAP 2007). Furthermore, Liddell and Baily (2001) were of the opinion that the lack of records of animal health treatment undermines the ability to track the inputs used during this animal production stage of the supply chain. This desktop study provides a review of disease control mechanisms by the OIE, Angola, Botswana, Namibia, South Africa and Zimbabwe as well as a summary of the diseases associated with game occurring in the aforementioned countries and the relevance as well as the risk of cross-infections related to some zoonotic diseases that have occurred with game. This review should therefore function as a quick reference guide for wildlife veterinarians, ecologists, farmers, hunters, slaughter staff, processors and public health professionals.

Background

Animal hosts, vectors and the environment in a natural ecosystem are in a dynamic balance, with occasional pathogen emergence and impact, but disease is not frequent when compared to artificial or domesticated animal farming systems. The success of preventing disease on a farm revolves around the abovementioned balance. Pressures on the environment such as the expected increase in human population (1 billion in Africa from 2009 to 2050), rapid urbanisation in developing countries and the global demand for livestock products (requiring higher stock rates) cause multiple animal health problems (Thornton *et al*. 2009). As an example, both scenarios of overstocking and introducing animals into habitats that they are not adapted to (e.g. lechwe in the Free State Province of South Africa and gemsbok in high rainfall areas) are becoming more common in South Africa. These drivers may cause disease vectors to increase with host species not suited for their habitat (and *vice versa*) to be affected first by a disease (Bester & Penzhorn 2002).

'Office Internationale des Epizooties' controlled diseases

Internationally, the OIE is the intergovernmental organisation responsible for improving animal health worldwide and is recognised as a reference organisation by the World Trade Organization (WTO). With the consideration of international spread, zoonotic potential, significant spread in native populations and emerging diseases as criteria, the OIE

keeps a list of so-called 'OIE listed' diseases for listing. All the countries relevant to this review (Angola, Botswana, Mozambique, Namibia, South Africa, Zimbabwe) are member countries of the OIE. It is required that all member countries will report to the OIE on incidences of any of the OIE listed diseases (OIE 2011a).

Disease control in Angola, Botswana, Mozambique, Namibia, South Africa, Zimbabwe

Policies and legislation normally form part of governmental animal health and food and meat control systems with the aim to prevent or control the spreading of disease to animals and humans. Regarding Southern Africa, Thomson and Penrith (2011) reported comprehensively on the animal health policy, legislation and trade in beef in the five participating states of the Kavango-Zambezi transfrontier conservation area (KAZA TFCA) which include Angola, Botswana, Namibia, Zambia and Zimbabwe and of which, Botswana, Namibia and Zimbabwe are neighboring countries of South Africa. Thomson and Penrith (2011) also list some trade related protocols of the Southern African Development Community (SADC) dealing with rules of origin for products to be traded between the member states of the SADC, sanitary and phytosanitary (SPS) rules, and technical barriers to trade (TBT). The following two tables provide non-exhaustive summaries of existing legislation in Angola, Botswana, Namibia, South Africa and Zimbabwe on the control of animal diseases and zoonosis (Table 1) and trade in meat and meat products (Table 2).

Disease occurrence in game in Angola, Botswana, Namibia, South Africa and Zimbabwe

Wildlife diseases have become more important in recent years and have led to an explosion of related knowledge (Gortázar *et al*. 2007). A non-exhaustive summary of zoonotic diseases that have occurred in wildlife animals in Angola, Botswana, Namibia, South Africa and Zimbabwe is therefore presented (Table 3).

Overview of some zoonotic diseases associated with game

Several worldwide outbreaks of animal related diseases such as bovine spongiform encephalopathy (BSE), avian influenza, RVF, et cetera and the associated media declarations have alerted consumers about the safety of meat in general. Because of these disease outbreaks, consumers are more informed and concerned about the safety and quality of meat products (Hoffman *et al*. 2005; Radder & Le Roux 2005). The industry has a moral responsibility towards the consumer in this regard. Gregory (2000) pointed out that the public puts their faith in the food authorities and the food industry to provide them with safe products. To achieve this, Gortázar *et al*. (2007) suggest that there should be close cooperation between multidisciplinary professionals such as wildlife ecologists, veterinarians and public health professionals. Regarding game meat production, certainly the game farmer, game hunting associations, processors (including those on farms), wholesale and retail markets and consumer interest groups should join in this multidisciplinary team. According to Bekker (2011), treatment of sick game animals is mostly done by veterinarians (59.5%) followed by trained farm staff (31.4%) and untrained farm staff (9.1%). From a veterinary health perspective, Blaha (1999) indicated that food animal practitioners play an important part in animal health management in general. In addition to veterinarians and other animal practitioners, veterinary public health practitioners can also play a role to ensure animal health and the provision of safe meat derived from slaughter animals to the consumer. Resulting from a desk top study, a non-exhaustive summary of the relevance as well as the risk of cross infections related to some of the zoonotic diseases that have occurred in the wild animals listed in Table 3 is also provided (Table 4).

TABLE 1: Summary of some legislation governing animal diseases in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Legislation	Botswana	Mozambique	Namibia	South Africa	Zimbabwe
Specific legislation governing animal diseases	*Diseases of Animals Act* No. 9 of 1977 (as amended) and subsidiary legislation	Regulation on Animal Health, Decree No. 8 of 2004 (as amended)	*Animal Diseases and Parasites Act* No. 13 of 1956 and regulations read with the Animal Health Bill of 2010	*Animal Diseases Act* No. 35 of 1984 (as amended)	*Animal Health Act* No. 5 of 1960 and Subsidiary Legislation (as amended)
	Diseases of Animals (Stock Feed) Regulations No. 126 of 2004	Regulation on Production and trade of forage for animal consumption, Order No. 23.358 of 1970	*Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act* No. 36 of 1947 (Law of the RSA) (as published 1996)	*Fertilizers, Farm Feeds, Agricultural Remedies Act* No. 36 of 1947 (as amended)	*Fertilizers, Farm Feeds and Remedies Act* No. 13 of 1996 and Subsidiary Legislation
	Branding of Cattle Act No. 19 of 1962 (as amended)	Regulation for livestock identification and registry, Decree No. 218 of 2002	*Stock Brands Act* No 24 of 1995 and regulations	*Animal Identification Act* No. 6 of 2002	*Brands Act* (Ord. 4 of 1900) and Subsidiary legislation
	Stock Theft Act No. 21 of 1996	–	*Stock Theft Act* No. 12 of 1990 (as amended)	*Stock Theft Act* No. 57 of 1959	*Stock Trespass Act* No. of 1991
	Cruelty to Animals Act Chapter 37.02 of 1936 (as amended)	–	*Animal Protection Act* No. 71 of 1962 (as amended)	*Prevention of Cruelty to Animals Act* No. 169 of 1993	*Prevention of Cruelty to Animals Act* No. 5 of 1960 (as amended)
Miscellaneous legislation governing animal diseases	*Matimela Act* No 25 of 1968 (as amended)	Sanitary Regulation for Animal Production Order No. 27 of 1975	*Medicines and Related Substances Control Act* No. 13 of 2003	–	Stock Remedies Regulations No. 11 of 1977 (as amended)
	Prevention of Rabies Act No. 48 of 1971	–	–	*International Health Regulations Act* No. 28 of 1974 (as amended)	Public Health (Port Health) Regulations No. 121 of 1995

Source: FAO 2012; Thomson and Penrith 2011; Whitehouse and Associates 2011

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.

TABLE 2: Summary of some legislation governing trade in meat and meat products in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Legislation	Botswana	Mozambique	Namibia	South Africa	Zimbabwe
Specific legislation governing trade in meat and meat products	*Botswana Meat Commission Act* 22 of 1965 (as amended)	–	*Meat Industry Act* No. 12 of 1981 (as amended)	*Meat Safety Act* No. 40 of 2000 and regulations	*Cold Storage Commission Act* No. 9 of 1960 (as amended) and regulations
	Livestock and Meat Industries Act No. 1 of 2007	–	*Meat Act* No. 220 of 1994	–	Public Health (Abattoir, Animal and Bird Slaughter and Meat Hygiene) Regulations No. 50 of 1995
	Botswana Agricultural Marketing Board Act No. 2 of 1974	Regulation on agricultural products.	–	*Agricultural Product Standards Act* No. 119 of 1990 and regulations	Agricultural Products Marketing (Livestock) (Carcass Classification and Grading) Regulations No. 182 of 2000
	Cattle Export and Slaughter Levy Act No. 10 of 2005	–	–	Veterinary Procedural Notices (VPNs) on export	*Produce Export Act* No. 4 of 1921 and Subsidiary Legislation
	Prohibition of Sale of Imported Cattle to the Botswana Meat Commission for Export to the European Union Regulations No. 101 of 1998)	Regulation on food imports, Ministerial Order No. 80 of 1987	–	Veterinary Procedural Notices (VPNs) on import	Animal Health (Import) Regulations No. 57 of 1989
	–	Standards Decree No. 2 of 1993	*Standards Act* No. 33 of 1962 (as amended)	*Standards Act* No. 29 of 1993	*Food and Food Standards Act* No. 25 of 1971 (as amended)
	Public Health Act No. 44 of 1971 (as amended)	*Public Health Act* No. 11 of 1990 and Ministerial Order No. 51 of 1984 on hygiene regulations for food handling establishments	*Public Health Act* No. 36 of 1919 (as amended)	*National Health Act* No. 61 of 2003 and Regulation 918 of 1999 on food premises requirements	*Public Health Act* No. 19 of 1924 (as amended)
	Food Control Act No. 11 of 1993	–	–	*Foodstuffs, Cosmetics and Disinfectant Act* No. 54 of 1972 (as amended)	–
Miscellaneous legislation governing trade in meat and meat products	*Control of Goods, Prices and Other Charges Act* No. 23 of 1973 (as amended) and Subsidiary legislation	–	*Prevention of Undesirable Residues in Meat Act* No. 21 of 1991 and regulations (as amended)	–	*Control of Goods Act* No. 12 of 1954 (as amended) 1996 and Subsidiary legislation
	Registration of Livestock Act No. 10 of 1921 (as amended)	–	–	–	*Factories and Works Act* No. 20 of 1948 (as amended)

Source: FAO 2012; Thomson and Penrith 2011; Whitehouse and Associates 2011
Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.

Emerging and re-emerging zoonotic diseases

Sleeman (2006) raised a concern that the handling and eating of game meat by humans will expose them to new micro-organisms and contaminants and will result in the emergence of new diseases. Over the past years, emerging diseases have frequently hit the headlines, of which most have a zoonotic foundation. Emerging and re-emerging zoonotic diseases are those that are newly identified, newly evolved or have occurred previously, but have more recently shown an increase in incidence or expansion into a new geographical area, host or vector range (Bengis *et al*. 2004; Paulsen & Smulders 2004). Though not zoonotic, an outbreak of African swine fever (ASF) has for example recently occurred in the eastern parts of the Gauteng Province and the western parts of the Mpumalanga Province of South Africa. Both these areas fall outside South Africa's ASF control area (GDARD 2012). Although the sources of these outbreaks are still unknown, the southward distribution and expansion of warthogs and tampans associated with the species could also contribute to the spreading of ASF beyond the borders of the ASF control areas (RMRDSA 2010). Although Daszak, Cunningham and Hyatt (2000) in their description of the relationship between wildlife, domestic animal and humans indicated that most emerging diseases impact on almost all groups, Pavlin, Schloegel and Daszak (2009) were of the opinion that most emerging infectious diseases are associated with wild animal zoonotic diseases. Infectious pathogens in wild animals as possible reservoirs have become increasingly important due to their substantial impacts on human health, domestic animal production, wildlife-based economies, wildlife conservation and global biodiversity (Bengis *et al*. 2004; Daszak *et al*. 2000; Paulsen & Smulders 2004). According to the FAO (2010), ± 60% of emerging infectious diseases of humans are zoonotic, of which 72% originate from wildlife. In addition, Christensen (1996) indicated that food of animal origin holds a threat to human health due to the diseases that it may transfer to humans and other animals.

Risk factors influencing the occurrence of diseases in wild animals are based on (1) the movements or translocations of wild or domestic animals and animal products, (2) the result of wildlife surplus, (3) the changing agricultural practices to farming with wild animals that support the transmission of pathogens between wild and domestic animals, (4) host and vector expansion, (5) the association with 'spill-over' from domestic animals to wildlife populations living in the same proximity, (6) the relation to human intervention, (7) diseases with no overt human or animal involvement, (8) the increase in human population and their relation to local and international travel and contact with wildlife populations and their products, (9) adaptations of pathogens themselves to certain situations, (10) changes in the environment and ecosystems that increase the transmission of infectious agents through open-air breeding and (11) enhancement of diagnostic and epidemiological techniques which assist in early detection of emerging or re-emerging infective agents

TABLE 3: Summary of some zoonotic diseases reported to have occurred in game in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Zoonotic diseases†	OIE listed‡	Notifiable§	Species	Countries	References
Anthrax *Bacillus anthracis*	X	X	Aardvark (*Orycteropus afer)*	Zimbabwe	OIE (2005)
		X	African wild cat (*Felis sylvestris)*	Namibia	OIE (2006a)
		X	Baboon (*Papio ursinus*)	South Africa; Zimbabwe	OIE (2010a, 2010b); OIE (2005)
		X	Black rhinoceros (*Diceros bicornis*)	Namibia	OIE (2006a)
		X	Buffalo (*Syncerus caffer caffer*)	Botswana	OIE (2005, 2007)
		X	Buffalo (*Syncerus caffer caffer*)	Mozambique	OIE (2005)
		X	Buffalo (*Syncerus caffer caffer*)	Namibia	OIE (2005)
		X	Buffalo (*Syncerus caffer caffer*)	South Africa	OIE (2007)
		X	Buffalo (*Syncerus caffer caffer*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Bushbuck (*Tragelaphus scriptus*)	Mozambique	OIE (2006a)
		X	Bushbuck (*Tragelaphus scriptus*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Bush pig (*Potamochoerus larvatus*)	Zimbabwe	OIE (2005)
		X	Cheetah (*Acinonyx jubatus*)	Botswana	OIE (2005)
		X	Cheetah (*Acinonyx jubatus*)	Namibia	OIE (2005, 2006a)
		X	Cheetah (*Acinonyx jubatus*)	Zimbabwe	OIE (2005)
		X	Civet (*Civettictis civetta*)	Zimbabwe	OIE (2005)
		X	Eland (*Taurotragus oryx*)	Namibia	OIE (2005)
		X	Eland (*Taurotragus oryx*)	Zimbabwe	OIE (2005)
		X	Elephant (*Loxodonta africana*)	Botswana	OIE (2005, 2007)
		X	Elephant (*Loxodonta africana*)	Mozambique	OIE (2005)
		X	Elephant (*Loxodonta africana*)	Namibia	OIE (2006a, 2007)
		X	Elephant (*Loxodonta africana*)	Zimbabwe	OIE (2005)
		X	Gemsbok (*Oryx gazella gazella*)	Namibia	OIE (2005, 2006a)
		X	Genet (*Genetta genetta)*	Zimbabwe	OIE (2005)
		X	Giraffe (*Giraffa camelopardalis*)	South Africa	OIE (2007)
		X	Giraffe (*Giraffa camelopardalis*)	Zimbabwe	OIE (2005, 2006a)
		X	Hippopotamus (*Hippopotamus amphibious*)	Botswana	OIE (2005)
		X	Hippopotamus (*Hippopotamus amphibious*)	Zimbabwe	OIE (2005)
		X	Impala (*Aepyceros melampus*)	Botswana	OIE (2005)
		X	Impala (*Aepyceros melampus*)	Zimbabwe	OIE (2005, 2006a)
		X	Jackal species (unidentified)	Zimbabwe	OIE (2005)
		X	Klipspringer (*Oreotragus oreotragus*)	Zimbabwe	OIE (2005)
		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	Botswana	OIE (2005)
		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	Namibia	OIE (2006a)
		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	South Africa	OIE (2005, 2006a)
		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Lechwe (*Kobus leche*)	Botswana	OIE (2005, 2007)
		X	Leopard (*Panthera pardus*)	Zimbabwe	OIE (2005)
		X	Lion (*Panthera leo*)	Botswana	OIE (2005)
		X	Mongoose species (unidentified)	Zimbabwe	OIE (2005)
		X	Nyala (*Tragelaphus angasii*)	South Africa	OIE (2007)
		X	Nyala (*Tragelaphus angasii*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Ostrich (*Struthio camelus*)	Namibia	OIE (2006a)
		X	Puku (*Kobus vardonii*)	Botswana	OIE (2005)
		X	Red hartebeest (*Alcelaphus buselaphus*)	Botswana	OIE (2005)
		X	Red hartebeest (*Alcelaphus buselaphus*)	Namibia	OIE (2006a)
		X	Reed buck (*Redunca arundinum*)	South Africa	OIE (2005)
		X	Roan antelope (*Hippotragus equinus*)	Botswana	OIE (2007)
		X	Roan antelope (*Hippotragus equinus*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Sable antelope (*Hippotragus niger*)	Botswana	OIE (2007)
		X	Sable antelope (*Hippotragus niger*)	Zimbabwe	OIE (2005)
		X	Springbok (*Antidorcas marsupialis*)	Namibia	OIE (2006a)
		X	Warthog (*Phacochoerus aethiopicus*)	Botswana	OIE (2005)
		X	Warthog (*Phacochoerus aethiopicus*)	Zimbabwe	OIE (2005)
		X	Waterbuck (*Kobus ellipsiprymnus*)	Zimbabwe	CFSPH (2007a); OIE (2005)
		X	Wild dog (*Lycaon pictus*)	Zimbabwe	OIE (2005)

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.
OIE, World Organization for Animal Health.
†, Zoonotic diseases are 'those diseases and infections, which are naturally transmitted between vertebrate animals and humans' (WHO 1994b).
‡, OIE (World Organisation for Animal Health – previously known as 'Organization Internationale des Épizooties') listed diseases refers to the list of transmissible disease agreed by the OIE International Committee and set out in Chapter 2.1.1 of the OIE Terrestrial Animal Health Code (OIE 2011a).
§, N, Notifiable disease: Officially notifiable disease in each country (available from OIE web site).

Table 3 continues on the next page →

TABLE 3 (Continues...): Summary of some zoonotic diseases reported to have occurred in game in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Zoonotic diseases†	OIE listed‡	Notifiable§	Species	Countries	References
Anthrax *Bacillus anthracis*		X	Wildebeest (*Connochaetes taurinus*)	Botswana	OIE (2007)
		X	Wildebeest (*Connochaetes taurinus*)	Namibia	OIE (2006a)
		X	Wildebeest (*Connochaetes taurinus*)	Zimbabwe	OIE (2005, 2006a)
		X	Zebra (*Equus burchelli*)	Botswana	OIE (2005)
		X	Zebra (*Equus burchelli*)	Namibia	OIE (2005, 2006a, 2007)
		X	Zebra (*Equus burchelli*)	Zimbabwe	OIE (2005)
Botulism *Clostridium botulinum*			Ostrich (*Struthio camelus*)	Namibia	OIE (2008)
			Springbok (*Antidorcas marsupialis*)	Namibia	OIE (2005)
			Waterfowl (unidentified)	South Africa	OIE (2005)
Brucellosis *Brucella spp.*	X	X	Buffalo (*Syncerus caffer caffer*)	South Africa	Godfroid (2002)
		X	Buffalo (*Syncerus caffer caffer*)	Zimbabwe	Madsen and Anderson (1995); Godfroid (2002)
		X	Eland (*Taurotragus oryx*)	South Africa	Godfroid (2002)
		X	Eland (*Taurotragus oryx*)	Zimbabwe	Madsen and Anderson (1995)
		X	Giraffe (*Giraffa camelopardalis*)	Zimbabwe	Madsen and Anderson (1995)
		X	Hippopotamus (*Hippopotamus amphibious*)	South Africa	Godfroid (2002)
		X	Impala (*Aepyceros melampus*)	South Africa	Godfroid (2002)
		X	Impala (*Aepyceros melampus*)	Zimbabwe	Madsen and Anderson (1995)
		X	Sable antelope (*Hippotragus niger*)	South Africa	OIE (2005)
		X	Waterbuck (*Kobus ellipsiprymnus*)	South Africa	Godfroid (2002)
		X	Zebra (*Equus burchelli*)	South Africa	Godfroid (2002)
Hydatid disease *(Echinococcus granulosis)*	X		Giraffe (*Giraffa camelopardalis angolensis)*	Namibia	Krecek *et al*. (1990)
			Kudu (*Tragelaphus strepsiceros*)	South Africa	Boomker, Horak and De Vos (1989)
			Lion (*Panthera leo*)	South Africa	OIE (2006a)
			Warthog (*Phacochoerus africanus*)	South Africa	Conradie (2008); Van Wyk and Boomker (2011)
			Sable antelope (*Hippotragus niger*)	Zimbabwe	OIE (2006a)
Rabies virus	X	X	Aardwolf *(Protoles cristata*)	Namibia	OIE (2006a)
		X	Aardwolf *(Protoles cristata*)	South Africa	OIE (2006a, 2007)
		X	African wildcat (*Felis lybica*)	South Africa	OIE (2007)
		X	African civet (*Civettictus civetta*)	South Africa	OIE (2006)
		X	Bat-eared fox (*Otocyon megalotis*)	Namibia	Swanepoel *et al*. (1993)
		X	Bat-eared fox (*Otocyon megalotis*)	South Africa	OIE (2006a, 2007)
		X	Black backed jackal (*Canis mesomelas*)	Botswana	OIE (2007)
		X	Black backed jackal (*Canis mesomelas*)	Namibia	OIE (2006a)
		X	Black backed jackal (*Canis mesomelas*)	South Africa	OIE (2006a, 2007)
		X	Buffalo (*Syncerus caffer caffer*)	Zimbabwe	OIE (2006a)
		X	Bushveld gerbil (*Tatera leucogaster*)	Zimbabwe	Rupprecht and Fekadu (1995)
		X	Cape fox (*Vulpes chama*)	Namibia	OIE (2006a)
		X	Caracal (*Felis caracal*)	South Africa	OIE (2007)
		X	Common duiker (*Sylvicapra grimmia*)	Namibia	OIE (2006a)
		X	Common duiker (*Sylvicapra grimmia*)	South Africa	OIE (2007)
		X	Common reedbuck (*Redunca arundinum*)	Zimbabwe	OIE (2007)
		X	Common genet (*Genetta genetta)*	South Africa	OIE (2006a, 2007)
		X	Eland (*Taurotragus oryx*)	Namibia	OIE (2006a)
		X	Eland (*Taurotragus oryx*)	South Africa	OIE (2007)
		X	Genet (unidentified species)	South Africa	Swanepoel *et al*. (1993)
		X	Honey badger (*Mellivora capensis*)	South Africa	OIE (2007)
		X	Impala (*Aepyceros melampus*)	Zimbabwe	OIE (2007)
		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	Namibia	Chomel, Belotto and Meslin (2007); Oberem and Oberem (2011); OIE (2005, 2006a, 2007, 2008, 2009); Swanepoel *et al*. (1993)
		X	Marsh mongoose (*Atilax paludinosus*)	South Africa	OIE (2007)
		X	Mongoose (*Cynictus* sp., *Rynchogale* sp.)	South Africa	OIE (2005); Swanepoel *et al*. (1993)
		X	Selous mongoose (*Paracynictus selousi*)	South Africa	OIE (2006a)
		X	Side striped jackal (*Canis adustus*)	South Africa	OIE (2006a; 2007)
		X	Jackal (unidentified species)	Botswana	Swanepoel *et al*. (1993)

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.
OIE, World Organization for Animal Health.
†, Zoonotic diseases are 'those diseases and infections, which are naturally transmitted between vertebrate animals and humans' (WHO 1994b).
‡, OIE (World Organisation for Animal Health – previously known as 'Organization Internationale des Épizooties') listed diseases refers to the list of transmissible disease agreed by the OIE International Committee and set out in Chapter 2.1.1 of the OIE Terrestrial Animal Health Code (OIE 2011a).
§, N, Notifiable disease: Officially notifiable disease in each country (available from OIE web site).

Table 3 continues on the next page →

TABLE 3 (Continues...): Summary of some zoonotic diseases reported to have occurred in game in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Zoonotic diseases†	OIE listed‡	Notifiable§	Species	Countries	References
Rabies virus		X	Jackal (unidentified species)	Namibia	Swanepoel *et al*. (1993)
		X	Jackal (unidentified species)	South Africa	Swanepoel *et al*. (1993)
		X	Jackal (unidentified species)	Zimbabwe	OIE (2005, 2006a); Swanepoel *et al*. (1993)
		X	Slender mongoose (*Herpestes sanguinea)*	South Africa	OIE (2005, 2006a)
		X	Small spotted cat (*Felis nigripes*)	South Africa	OIE (2006a)
		X	Suricate (*Suricata suricata*)	Namibia	OIE (2005, 2006a)
		X	Suricate (*Suricata suricata*)	South Africa	OIE (2005, 2007)
		X	Wild dog (*Lycaon pictus*)	Namibia	OIE (2006a)
		X	Wild dog (*Lycaon pictus*)	South Africa	Hofmeyr *et al*. (2000); Oberem and Oberem (2011)
		X	Wild dog (*Lycaon pictus*)	Zimbabwe	OIE (2006a)
		X	Yellow mongoose (*Cynictus penicillata)*	South Africa	OIE (2006a, 2007)
Rift Valley fever virus	X	X	Alpacas (*Vicugna pacos*)	South Africa	OIE (2010a, 2010b)
		X	Buffalo (*Syncerus caffer caffer*)	South Africa	OIE (2010b)
		X	Buffalo (*Syncerus caffer caffer*)	Zimbabwe	Oberem and Oberem (2011)
		X	Black rhinoceros (*Diceros bicornis*) (showed antibodies)	Zimbabwe	Oberem and Oberem (2011)
		X	Bontebok (*Damaliscus pygorgus*)	South Africa	OIE (2010a, 2010b)
		X	Eland (*Taurotragus oryx*)	South Africa	OIE (2010a, 2010b)
		X	Fallow deer (*Dama dama*)	South Africa	OIE (2010a, 2010b)
		X	Llama (*Lama glama*)	South Africa	OIE (2010a, 2010b)
		X	Sable antelope (*Hippotragus niger*)	South Africa	OIE (2010a, 2010b)
		X	Springbok (*Antedorcas marsupialis*)	South Africa	OIE (2010a, 2010b)
		X	Waterbuck (*Kobus ellipsiprymnus*) (showed antibodies)	South Africa	OIE (2010a, 2010b)
		X	Waterbuck (*Kobus ellipsiprymnus*) (showed antibodies)	Zimbabwe	Oberem and Oberem (2011)
		X	White rhinoceros (*Ceratotherium simum*) (showed antibodies)	Zimbabwe	Oberem and Oberem (2011)
Toxoplasmosis *Toxoplasma gondii*			Lion (*Panthera leo*)	Zimbabwe	OIE (2006a)
Trichinellosis *Trichinella* spp.	X		Buffalo (*Syncerus caffer caffer*)	South Africa	OIE (2006a)
			Civet (*Cevettictis civetta*)	South Africa	Oberem and Oberem (2011)
		X	Crocodile (*Crocodylus niloticus*)	Zimbabwe	OIE (2006, 2007, 2008); Pozio (2005)
			Hyaena (*Crocuta crocuta*)	South Africa	Oberem and Oberem (2011)
			Jackal (unidentified)	South Africa	Oberem and Oberem (2011)
		X	Lion (*Panthera leo*)	Zimbabwe	OIE (2007)
			Warthog (*Phacochoerus africanus*)	South Africa	Oberem and Oberem (2011)
Tuberculosis *Mycobacterium bovis*	X	X	Baboon (*Papio ursinus*)	South Africa	Ayele *et al*. (2004); Bengis, Kock and Fisher (2002); Oberem and Oberem (2011)
		X	Blesbok (*Damaliscus dorcas phillipsi*)	South Africa	Oberem and Oberem (2011)
		X	Buffalo (*Syncerus caffer caffer*)	South Africa	Ayele *et al*. (2004); Bengis (2002); Bengis, Kock and Fisher (2002); Hlokwe *et al*. (2011); Cook (2005); Keet *et al*. (1996); Michel (2002); Michel *et al*. (2006); Oberem and Oberem (2011); OIE (2005, 2006a, 2009); Shitaye, Tsegaye and Pavlik (2007)
		X	Bushbuck (*Tragelaphus scriptus*)	South Africa	OIE (2007, 2008)
		X	Bush pig (*Potamochoerus larvatus*)	South Africa	Hlokwe *et al*. (2011); Oberem and Oberem (2011)
		X	Cheetah (*Acinonyx jubatus*)	South Africa	Ayele *et al*. (2004); Bengis (2002); Oberem and Oberem (2011)
		X	Common duiker (*Sylvicapra grimmia*)	South Africa	Oberem and Oberem (2011)
		X	Eland (*Taurotragus oryx*)	South Africa	Oberem and Oberem (2011)
		X	Honey badger (*Mellivora mellivora*)	South Africa	Bengis (2002); Oberem and Oberem (2011)
		X	Hyaena (*Crocuta crocuta*)	South Africa	Bengis (2002); OIE (2007)
		X	Impala (*Aepyceros melampus*)	South Africa	Oberem and Oberem (2011); OIE (2005, 2008)

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.
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Table 3 continues on the next page →

TABLE 3 (Continues...): Summary of some zoonotic diseases reported to have occurred in game in Angola, Botswana, Namibia, South Africa and Zimbabwe.

Zoonotic diseases†	OIE listed‡	Notifiable§	Species	Countries	References
Tuberculosis *Mycobacterium bovis*		X	Kudu (*Tragelaphus strepsiceros strepsiceros*)	South Africa	Bengis (2002); Bengis *et al*. (2001); Keet *et al*. (2001); Shitaye, Tsegaye and Pavlik (2007); Oberem and Oberem, (2011); OIE (2006a, 2008)
		X	Large spotted genet (*Genetta tigrina*)	South Africa	Oberem and Oberem (2011)
		X	Leopard (*Panthera pardus*)	South Africa	OIE (2005)
		X	Lion (*Panthera leo*)	South Africa	Ayele *et al*. (2004); Bengis (2000); Hlokwe *et al*. (2011); Oberem and Oberem (2011); OIE (2005, 2006a, 2007, 2008)
		X	Lion (*Panthera leo*)	Zimbabwe	OIE (2008)
		X	Spotted hyena (*Crocuta crocuta*)	South Africa	Oberem and Oberem (2011)
		X	Surricate (*Suricata suricata*)	South Africa	Oberem and Oberem (2011); OIE (2006a, 2008)
		X	Warthog (*Phacochoerus africanus*)	South Africa	Oberem and Oberem (2011); OIE (2006a)
Tuberculosis *Mycobacterium tuberculosis*			Baboon (*Papio ursinus*)	South Africa	OIE (2008)
			Banded mongoose (*Mungos mungo*)	Botswana	Alexander *et al*. (2002)
			Buffalo (*Syncerus caffer caffer*)	South Africa	Alexander *et al*. (2002)
			Surricate (*Suricata suricata*)	South Africa	Alexander *et al*. (2002)

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.
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§, N, Notifiable disease: Officially notifiable disease in each country (available from OIE web site).

(Bengis *et al*. 2004; Daszak *et al*. 2000; Gortázar *et al*. 2007). Bengis *et al*. (2004) warned that the geographical expansion of pathogens and/or their vectors as a result of global warming and other associated climatic changes and the continued collision between human populations and wildlife in the human endeavour to advance into new habitats and ecosystems will increase the risk of new emerging diseases in years to come. They also pointed out that the most likely populations to be affected are those in less developed countries and poorer communities. Several opportunities exist for diseases to spread from one animal to another as they move around and associate with each other. Diseased animals, for example, die and are left to scavengers to clean, which in turn are infected and they spread the disease further. This process implies, however, that there may be some extent of dilution which will make the organisms responsible for disease less abundant and less likely to persist. Dilution occurs when other hosts in a community are also exposed instead of only being present in one highly competent reservoir host species alone (Begon 2008). Ogden and Tsao (2009) indicated that this method of dilution will result in fewer new infections and thereby reduce the basic reproductive number (R_0) of the pathogen. In their study on Lyme disease, however, they also indicated that the extent of amplification or dilution of the disease is dependent on the mechanisms of completion, host contact rates and host resistance. Bengis *et al*. (2002) indicated that the most probable transmission mechanisms include (1) aerosols contaminating feed, water and range and (2) flightless vectors such as ticks, and winged vectors such as mosquitoes, and that one of the most important factors in disease transmission between livestock and wildlife is the creation of new interfaces. In addition to this, the increase in the distribution of game meat may also now be seen as a possible risk in the spreading of diseases.

Disease surveillance and management

From a study by Bekker (2011), there is evidence of minimal disease surveillance and management amongst game farmers. According to Paskin (1999) the early detection of disease increases the chance to arrest the disease prior to it causing damage. Detection requires that a surveillance system must be in place as required by the GlobalGAP integrated farm assurance standard (GlobalGAP 2007). Surveillance activities can be defined as:

> All regular activities aimed at ascertaining the health status of a given population with the aim of early detection and control of animal diseases of importance to national economies, food security and trade. (Paskin 1999)

Disease surveillance is not a haphazard activity and therefore requires proper planning and techniques. A summary of aspects that Bengis *et al*. (2002) have provided as guidance in this regard is presented here (Table 5).

From an economic perspective, it also makes sense to have proper prevention measures in place. The OIE (2006b) indicated in a report that dealt with an economical analysis of the costs of prevention versus the costs of outbreak, that the benefits accrued from improved prevention and control measures outweigh the costs of prevention and control investment. As an example, Tambi *et al*. (1999) proved that rinderpest control in Africa through the implementation of the Pan-African Rinderpest Campaign (PARC) in 1986 has been a wise public investment decision and that both producers and consumers gained from it economically.

Conclusion

This review shows that game plays an important role in animal disease spreading to other domesticated and wild animals and provides summaries of the occurrence of some

TABLE 4: Summary of relevance as well as the risk of cross infections related to some zoonotic diseases that have occurred in wild animals.

Disease and agent	Relevance	Main risks
Anthrax (*Bacillus anthracis*)	Occupational hazard (Herenda & Chalmers, 1994); Affects most mammals and several bird species (CFSPH, 2007a); Particularly important in herbivores (CFSPH, 2007a)	Worldwide – areas with alkaline, calcareous soil, and warm environment (Oberem & Oberem, 2011); Spore forming, resistant to extreme temperature, disinfectants and desiccation (CFSPH, 2007a; Oberem & Oberem, 2011); Blowflies, scavengers and vultures spread organism (Herenda & Chalmers, 1994; Oberem & Oberem, 2011); Crosses the interface between domestic and wild animals; Unvaccinated animals as prevention of the disease (Oberem & Oberem, 2011)
Botulism (*Clostridium botulinum*)	Often seen in cattle in South Africa (CFSPH, 2005a); Food poisoning to humans (Herenda & Chalmers, 1994)	Grows under anaerobic conditions (CFSPH, 2005a); Neurotoxic food poisoning through contaminated meat (CFSPH, 2005a); Botulism toxins are heat labile (Herenda & Chalmers, 1994); Soil and water contamination occurs from faeces and decomposing animal tissue and in plant material (Herenda & Chalmers, 1994); Common in phosphate-poor regions – animals chew bones or dead animal carcasses as a result of phosphate deficiency (CFSPH, 2005a); Unvaccinated animals, especially giraffe (Oberem & Oberem, 2011)
Brucellosis (*Brucella* spp.)	Economic impact – reproductive losses in animals (CFSPH, 2009a); Zoonotic importance in rural areas in developing countries (Herenda & Chalmers, 1994); Occupational hazard (Herenda & Chalmers); Human infection through infected meat, mucous membrane and damaged skin Economically important (Gortázar *et al*., 2007)	Worldwide; Transmitted between animals by contact with placenta, foetus, foetal fluids, vaginal discharges, feed and water(CFSPH, 2009a); Wild and domestic ungulate interface increases the risk to humans; Movement of wild and domestic animals (Oberem & Oberem, 2011) Movement of animals (Gortázar *et al*., 2007)
Hydatidosis (*Echinococcus* spp.)	Economic impact – condemnation of affected organs (Herenda & Chalmers, 1994); Humans are accidental hosts by eating raw or poorly cooked infected meat (CFSPH, 2009b)	Worldwide; Tape worm lives in the intestines of carnivores and therefore spreads the parasite through faeces. Wildlife act as important reservoirs; Expansion or introduction of hosts (Gortázar *et al*., 2007); Emerging or re-emerging in some areas (CFSPH, 2009b)
Rabies (*Lyssavirus*)	Rabies kills between 50 000 and 100 000 humans per year (Oberem & Oberem, 2011); Occupational hazard (Herenda and Chalmers, 1994); Vaccination of wild dog packs in endemic areas (Oberem & Oberem, 2011)	All mammals are susceptible, including man (Sleeman, 2006); Worldwide except for certain islands (CFSPH, 2009c); Re-emerging disease mostly in developing countries (CFSPH, 2009c); 'Spillover' into other domestic animals and man (Oberem & Oberem, 2011); Expansion or introduction of hosts, movement of animals (Gortázar *et al*., 2007)
Rift Valley fever (*Phlebovirus*)	Heavy economic impact (Gortázar *et al*., 2007); Occupational hazard – exposure to infected aerosols, blood, tissue and aborted foetuses (Herenda & Chalmers, 1994)	Endemic in sub-Saharan Africa (Herenda & Chalmers, 1994; CFSPH, 2007b); Presence of mosquitoes (carrier) during heavy spring rains (Herenda & Chalmers, 1994); Wildlife abundance, open-air farming (Gortázar *et al*., 2007)
Toxoplasmosis (*Toxoplasma gondii*)	Humans infected by ingesting infected raw or undercooked animal tissue (CFSPH, 2005b; Herenda & Chalmers, 1994)	Open-air farming (Gortázar *et al*., 2007); Flies and cockroaches can act as mechanical vectors (CFSPH, 2005b)
Trichinosis (*Trichinella* spp.)	Humans infected by consumption of raw or undercooked meat (Herenda & Chalmers, 1994); Game meat is a common source (Sleeman, 2006); Stillbirths with women (Capó & Despommier, 1996)	Eating raw warthog meat (Oberem & Oberem, 2011); Microscopic cysts cannot be identified during meat inspection (Herenda & Chalmers, 1994); Pathogen introduction by pigs and rats Pozio (2005); Open-air farming (Gortázar *et al*., 2007)
Tuberculosis (*Mycobacterium bovis*)	Wild animals serve as reservoirs for the disease; Nearly all warm blooded animals are affected (Ayele *et al*., 2004); People with AIDS are more susceptible (Ayele *et al*., 2004); Heavy economic impact (Gortázar *et al*., 2007)	Animals infected by inhaling dust particles as well as by ingestion of contaminated feed or water (CFSPH, 2009d; Herenda & Chalmers, 1994); 'Spillover' to rural communities is increasing (Zinsstag *et al*., 2008; Shitaye, Tsegaye & Pavlik, 2007); 'Spillover' to other animals (Oberem & Oberem, 2011); Movement of animals, wildlife overabundance, open-air farming (Gortázar *et al.,* 2007); Non-control of interface between wildlife and cattle (Gortázar *et al*., 2007; Oberem & Oberem, 2011)
Tuberculosis (*Mycobacterium tuberculosis*)	Disease in animals probably originated as an infection of humans (Montali, Mikota & Cheng, 2001); Occupational hazard (Oh *et al*., 2002); Buffaloes (*Syncerus caffer*) are reservoir hosts of BTB in South African wildlife populations (Hlokwe *et al*., 2011)	Threatens South African wildlife (Hlokwe *et al*., 2011); Zoos are a particular public health concern due to close contact between animals and humans (Oh *et al*., 2002); Several *M. bovis* genotypes exist (Hlokwe *et al*., 2011; Michel *et al*., 2009)

Note: Please see the full reference list of the article, Bekker, J.L., Hoffman, L.C. & Jooste, P.J., 2012, 'Wildlife-associated zoonotic diseases in some southern African countries in relation to game meat safety: A review', *Onderstepoort Journal of Veterinary Research* 79(1), Art. #422, 12 pages. http://dx.doi.org/10.4102/ojvr.v79i1.422, for more information.

TABLE 5: Factors to consider with disease detection and management.

Disease detection	Disease management
• Investigate reports of abnormal clinical signs • Training of lay staff to collect samples and record data sheets • Conduct diagnostic necropsies on carcasses. Aetiological cause of morbidity is important • Examine road and hunter kills • Conduct veterinary and veterinary public health inspections • Disease monitoring • Veterinary examination of captured animals • Veterinary supervision at holding facilities • Sero-surveys • Rodent and vector trapping	• Disease investigation best in cooperation with veterinarians and wildlife experts • Use of enclosed control areas where possible • Vaccination and vector control for arthropod diseases • Control diseases in domestic stock • Prevent contact between infected domestic animals and wildlife • Improve delivery of animal health services

Source: Bengis, R.G., Kock, R.A. & Fisher, J., 2002, 'Infectious animal diseases: The wildlife/livestock interface', *Scientific and Technical Review (OIE)* 21, 53–65. PMid:11974630

zoonotic diseases in game in Angola, Botswana, Namibia, South Africa and Zimbabwe, current disease and meat (food) control legislation in these countries and the relevance as well as the risk of cross-infections related to some zoonotic diseases that have occurred with game. Of particular concern to game meat safety are the zoonotic diseases that can be transmitted through the consumption of meat and meat products. The consumer has to be safeguarded from possible infection (zoonosis) and therefore meat inspection of game carcasses is essential (Skinner 1970). However, as previously indicated, several of the zoonotic diseases are also an occupational hazard as farmers, farm workers, hunters, slaughter staff, veterinarians, processors, et cetera , can become infected whilst handling the animals or meat thereof.

Pavlin *et al*. (2009) indicated that the simplest way to minimise the risk of zoonotic disease is the reduction of opportunities for transmission of diseases from wildlife to humans. To achieve this, Gortázar *et al*. (2007) suggested a multidisciplinary approach of wildlife ecologists, veterinarians and public health professionals. In addition, Oberem and Oberem (2011) pointed out the importance of disease-causing investigations

carried out on dead animals by experts who will know how to prevent further spreading of the diseases, especially zoonotic diseases. In this regard, the animal disease investigation laboratories also play an important role as they can assist with the carrying out of routine investigations and surveillance programmes (especially notifiable, controlled and zoonotic diseases and research on animal disease and related issues) (Geering, Roeder & Obi 1999). The implementation of a comprehensive surveillance plan should be of critical importance to veterinary authorities (Gortázar *et al*. 2007) and will require innovative measures to improve vigilance (Bengis *et al*. 2004). In this regard, the South African Department of Agriculture, Forestry and Fisheries (DAFF), for example, have an epidemiology division whose mandate is contained in the *Animal Diseases Act* (Act No. 35 of 1984) (as amended) (South African Government 1984) and its main functions include (Ungerer 2008):

- developing, analysing and auditing policies for the surveillance of animal diseases and diseases that can be transmitted from animals to humans
- developing, analysing and auditing policies on disease reporting in the different provinces of South Africa
- conducting risk assessments at a national level
- acting as contact point for communicating risk and the occurrence of animal diseases in South Africa to foreign governments and international bodies
- managing animal disease information and reporting thereof to the World Organization for Animal Health (OIE), Southern African Development Community (SADC) and the African Union (AU)
- managing of animal disease information by using a Geographic Information System
- managing of animal disease early warning systems (SADC, nationally and internationally)
- ensuring that there are adequate government veterinary laboratory services at provincial level and elsewhere, for example in the Kruger National Park, and by working in collaboration with the Onderstepoort Veterinary Institute of the Agricultural Research Council
- enforcement of quality systems in diagnostic veterinary laboratories
- auditing the enforcement of policy for reference laboratories.

However, these measures will only be effective if wild game ranchers follow the correct procedures in contacting the relevant authorities. Bekker (2011), however, has illustrated negligence in certain farming practices and a lack of knowledge of farmers that may impact negatively on a country's surveillance plan. To prevent a situation where farmers and other stakeholders may not place a high value on participating in achieving the main objectives of a surveillance plan, it is recommended that policy makers and law enforcers at all levels of government in collaboration with other wildlife industry stakeholders such as wildlife veterinarians, ecologists, farmers, hunters, slaughter staff, processors and public health professionals establish strategies to ensure that all stakeholders are adequately trained in the role that they play in the control of zoonotic diseases in game. Industry organisations such as farmer and hunting associations as 'bridging organisations' have a role to play with the provision of information or knowledge by (1) encouraging dialogue between governmental policy makers and industry, (2) acting as channels for policy makers to direct and apply new strategies at the industry-level, (3) assisting with the bottom-up flow of information at industry level and (4) providing platforms for information exchange (Berkes 2009; Tarnoczi & Berkes 2010). In addition, bridging organisations can provide a platform for trust building, sense making, learning, vertical and horizontal collaboration, and conflict resolution (Hahn *et al*. 2006). Meaningful knowledge is most likely to result in concept development, attitudinal change and positive behaviour.

Acknowledgements

We would like to thank the library and information services of the Tshwane University of Technology library for their support in obtaining information used in this review. This study was also partly funded by Stellenbosch University Overarching Strategic Plan Food Security Initiative.

Competing interests

The authors declare that they have no financial or personal relationship(s) which may have inappropriately influenced them in writing this paper.

Authors' contributions

This manuscript forms part of a PhD study where the student J.L.B. (Tshwane University of Technology) was mainly responsible for the compilation of the review published on zoonotic diseases. L.C.H. (Stellenbosch University) was the first study promoter and P.J.J. (Tshwane University of Technology) was the second study promoter.

References

Alexander, D.J., 2000, 'A review of avian influenza in different bird species', *Veterinary Microbiology* 74(1–2), 3–13. http://dx.doi.org/10.1016/S0378-1135(00)00160-7

Alexander, K.A., Pleydell, E., Williams, M.C., Lane, E.P., Nyange, J.F.C. & Michel, A.L., 2002, 'Mycobacterium tuberculosis: An emerging disease of free-ranging wildlife', *Emerging Infectious Diseases* 8(6), 598. http://dx.doi.org/10.3201/eid0806.010358, PMid:12023916

Ayele, W., Neill, S., Zinsstag, J., Weiss, M. & Pavlik, I., 2004, 'Bovine tuberculosis: An old disease but a new threat to Africa', *International Journal of Tuberculosis and Lung Disease* 8(8), 924–937. PMid:15305473

Begon, M., 2008, 'Effects of host diversity on disease dynamics', in R.S. Ostfeld, F. Keesing & V. Eviner (eds.), *Infectious disease ecology: Effects of ecosystems on disease and of disease on ecosystems*, pp. 12–29, Princeton University Press, Princeton.

Bekker, J.L., 2011, 'A food safety plan for game meat in South Africa', D. Tech thesis, Pretoria, Dept. of Environmental Health, Tshwane University of Technology.

Bengis, R.G., 2002, 'State controlled diseases and game ranching', in B.L. Penzhorn (ed.), *November 2002, Symposium on game ranch planning and management*, pp. 60–64, Wildlife Group of the South African Veterinary Association, Onderstepoort, Pretoria.

Bengis, R., Keet, D., Michel, A. & Kriek, N., 2001, 'Tuberculosis, caused by *Mycobacterium bovis* in a kudu (*Tragelaphus strepsiceros*) from a commercial game farm in the Malelane area of the Mpumalanga province, South Africa', *Onderstepoort Journal of Veterinary Research* 68(3), 239. PMid:11769357

Bengis, R.G., Kock, R.A. & Fisher, J., 2002, 'Infectious animal diseases: The wildlife/livestock interface', *Scientific and Technical Review (OIE)* 21, 53–65. PMid:11974630

Bengis, R.G., Leighton, F.A., Fischer, J.R., Artois, M., Mörner, T. & Tate, C.M., 2004, 'The role of wildlife in emerging and re-emerging zoonosis', *Scientific and Technical Review (OIE) 23*(2), 497–511. PMid:15702716

Berkes, F., 2009, 'Evolution of co-management: Role of knowledge generation, bridging organizations and social learning', *Journal of Environmental Management* 90(5), 1692–1702. http://dx.doi.org/10.1016/j.jenvman.2008.12.001, PMid:19110363

Bester, P. & Penzhorn, B., 2002, 'Disease prevention and management on game ranches', in B.L. Penzhorn (ed.), *Proceedings of a Symposium on Game Ranch Planning and Management*, pp. 23–30, Onderstepoort, Pretoria.

Blaha, T., 1999, 'Epidemiology and quality assurance application to food safety', *Preventive Veterinary Medicine* 39(2), 81–92. http://dx.doi.org/10.1016/S0167-5877(98)00150-0

Boomker, J., Horak, I.G. & De Vos, V., 1989, 'Parasites of South African wildlife. IV. Helminths of kudu, *Tragelaphus strepsiceros*, in the Kruger National Park', *Onderstepoort Journal of Veterinary Research* 56(2), 111–121. PMid:2748130

Capó, V. & Despommier, D.D., 1996, 'Clinical aspects of infection with *Trichinella* spp.', *Clinical Microbiology Reviews* 9(1), 47. PMid:8665476

Center for Food Security and Public Health (CFSPH), 2005a, *Botulism*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2005b, *Toxoplasmosis*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2007a, *Anthrax*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2007b, *Rift Valley fever*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2009a, *Brucellosis*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2009b, *Echinococcus*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2009c, *Rabies*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Center for Food Security and Public Health (CFSPH), 2009d, *Bovine tuberculosis*, College of Veterinary Medicine, Iowa State University, Iowa, viewed 19 May 2011, from http://www.cfsph.iastate.edu

Chan, J., Baxter, C. & Wenman, W.M., 1989, 'Brucellosis in an Inuit child, probably related to caribou meat consumption', *Scandinavian Journal of Infectious Diseases* 21(3), 337–338. http://dx.doi.org/10.3109/00365548909035706, PMid:2569231

Chomel, B.B., Belotto, A. & Meslin, F.X., 2007, 'Wildlife, exotic pets, and emerging zoonoses', *Emerging Infectious Diseases* 13(1), 6. http://dx.doi.org/10.3201/eid1301.060480, PMid:17370509

Christensen, S.D., 1996, 'An overview of the food safety situation for the human population in African developing countries: A veterinary public health approach', in R. Lindberg (ed.), *Veterinary medicine – Impacts on human health and nutrition in Africa*, Proceedings of an international conference, International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia, SLU/Repro, Uppsala, August 27–31, 1995, pp. 157–163.

Conradie, I., 2008, 'The prevalence of helminths in warthogs, bushpigs and some antelope species in Limpopo province, South Africa', MSc degree in Veterinary Tropical Disease, Faculty of Veterinary Science, University of Pretoria, Pretoria.

Cleaveland, S., Laurenson, M.K. & Taylor, L.H., 2001, 'Diseases of humans and their domestic mammals: Pathogen characteristics, host range and the risk of emergency', *Philosophical Transactions of the Royal Society of London B Biological Sciences* 356(1411), 991–999. http://dx.doi.org/10.1098/rstb.2001.0889, PMid:11516377

Cook, R.A., 2005, 'Emerging diseases at the interface of people, domestic animals and wildlife: The role of wildlife in our understanding of highly pathogenic avian influenza', *Yale Journal of Biology and Medicine* 78(5), 343. PMid:17132341

Cosivi, O., Meslin, F., Daborn, C. & Grange, J., 1995, 'Epidemiology of *Mycobacterium bovis* infection in animals and humans, with particular reference to Africa', *Revue scientifique et technique – Office International des Épizooties* 14(3), 733. PMid:8593405

Cosivi, O., Grange, J.M., Daborn, C., Raviglione, M.C., Fujikura, T., Cousins, D. *et al*., 1998, 'Zoonotic tuberculosis due to *Mycobacterium bovis* in developing countries', *Emerging Infectious Diseases* 4(1), 59. http://dx.doi.org/10.3201/eid0401.980108, PMid:9452399

Daszak, P., Cunningham, A.A. & Hyatt, A.D., 2000, 'Emerging infectious diseases of wildlife –Threats to biodiversity and human health', *Science* 287(5452), 443–449. http://dx.doi.org/10.1126/science.287.5452.443, PMid:10642539

De la Rua-Domenech, R., 2006, 'Human *Mycobacterium bovis* infection in the United Kingdom: Incidence, risks, control measures and review of the zoonotic aspects of bovine tuberculosis', *Tuberculosis,* 86(2), 77–109. http://dx.doi.org/10.1016/j.tube.2005.05.002, PMid:16257579

Food and Agricultural Organization (FAO), 2010, *Bushmeat consumption, wildlife trade and global public health risks,* Agricultural Department, Animal Production and Health Division, viewed 17 May 2011, from http://www.fao.org

Food and Agricultural Organization (FAO), 2011, *No more deaths from rinderpest,* Agricultural Department, Animal Production and Health Division, viewed 21 June 2011, from http://www.fao.org

Food and Agricultural Organization (FAO), 2012, *International Portal on Food Safety, Animal and Plant Health (IPFSAPH)*, viewed 21 June 2011, from http://www.ipfsaph.org

Gauteng Department of Agriculture and Rural Development (GDARD), 2012, 'GDARD Bulletin, 2/1/2012', viewed 15 June 2011, from http://www.gdard.gpg.gov.za

Gauthier-Clerc, M., Lebarbenchon, C. & Thomas, F., 2007, 'Recent expansion of highly pathogenic avian influenza H5N1: A critical review', *Ibis* 149, 202–214. http://dx.doi.org/10.1111/j.1474-919X.2007.00699.x

Geering, W.A., Roeder, P.L. & Obi, T.U., 1999, 'Manual on the preparation of national animal disease emergency preparedness plans', Food and Agriculture Organization (FAO) of the United Nations, Rome, viewed 16 September 2012, from http://www.fao.org

GlobalGAP, 2007, '*Integrated farm assurance standard',* Germany, viewed 15 May 2011, from http://www.global gap.org

Godfroid, J., 2002, 'Brucellosis in wildlife', *Revue scientifique et technique – Office International des Épizooties* 21(2), 277–286.

Gortázar, C., Ferroglio, E., Höfle, U., Frölich, K. & Vicente, J., 2007, 'Diseases shared between wildlife and livestock: A European perspective', *European Journal of Wildlife Research* 53, 241–256. http://dx.doi.org/10.1007/s10344-007-0098-y

Gregory, N.G., 2000, 'Consumer concerns about food', *Outlook on Agriculture* 29(4), 251–257. http://dx.doi.org/10.5367/000000000101293310

Hahn, T., Olsson, P., Folke, C. & Johansson, K., 2006, 'Trust-building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive co-management of a wetland landscape around Kristianstad, Sweden', *Human Ecology* 34(4), 573–592. http://dx.doi.org/10.1007/s10745-006-9035-z

Harrison, L.H., Ezzell, J.W., Abshire, T.G., Kidd, S. & Kaufmann, A.F., 1989, 'Evaluation of serologic tests for diagnosis of anthrax after an outbreak of cutaneous anthrax in Paraguay', *Journal of Infectious Diseases* 160(4), 706–710. http://dx.doi.org/10.1093/infdis/160.4.706, PMid:2507648

Herenda, D.C. & Chalmers, P., 1994, '*Manual on meat inspection for developing countries',* Food & Agriculture Organization, viewed 20 May 2008, from http://www.fao.org/ docrep/003/t0756e/T0756E00.htm

Hlokwe, T.M., Jenkins, A.O., Streicher, E.M., Venter, E.H., Cooper, D., Godfroid, J. *et al*., 2011, 'Molecular characterisation of *Mycobacterium bovis* isolated from African buffaloes (*Syncerus caffer*) in Hluhluwe-iMfolozi Park in KwaZulu-Natal, South Africa', *Onderstepoort Journal of Veterinary Research* 78(1), 6. http://dx.doi.org/10.4102/ojvr.v78i1.232

Hoffman, L.C., Muller, M., Schutte, de W., Calitz, F.J. & Crafford, K., 2005, 'Consumer expectations, perceptions and purchasing of South African game meat', *South African Journal of Wildlife Research* 35(1), 33–42.

Hofmeyr, M., Bingham, J., Lane, E., Ide, A. & Nel, L., 2000, 'Rabies in African wild dogs (*Lycaon pitus*) in the Madikwe Game Reserve, South Africa', *Veterinary Record* 146(2), 50. http://dx.doi.org/10.1136/vr.146.2.50, PMid:10678814

Keet, D.F., Kriek, N.P.J., Penrith, M.L., Michel, A. & Huchzermeyer, H., 1996, 'Tuberculosis in buffaloes (*Syncerus caffer*) in the Kruger National Park: Spread of the disease to other species', *Onderstepoort Journal of Veterinary Research* 63, 239–244. PMid:8917861

Keet, D., Kriek, N., Bengis, R. & Michel, A., 2001, 'Tuberculosis in kudus (*Tragelaphus strepsiceros*) in the Kruger National Park', *Onderstepoort Journal of Veterinary Research* 68(3), 225. PMid:11769355

Krecek, R.C., Boomker, J., Penzhorn, B.L. & Scheepers, L., 1990, 'Internal parasites of giraffes *(Giraffa camelopardalis angolensis)* from Etosha National Park, Namibia', *Journal of Wildlife Diseases* 26(3), 395–397. PMid:2388363

Li, H., Shen, D.T., Jessup, D.A., Knowles, D.P., Gorham, J.R., Thorne, T. *et al*., 1996, 'Prevalence of antibody to malignant catarrhal fever virus in wild and domestic ruminants by competitive-inhibition ELISA', *Journal of Wildlife Diseases* 32(3), 437–443. PMid:8827669

Liddell, S. & Bailey, D., 2001, 'Market opportunities and threats to the US pork industry posed by traceability systems', *International Food and Agribusiness Management* 4, 287–302. http://dx.doi.org/10.1016/S1096-7508(01)00081-7

Madsen, M. & Anderson, E.C., 1995, 'Serologic survey of Zimbabwean wildlife for brucellosis', *Journal of Zoo and Wildlife Medicine* 26(2), 240–245.

Michel, A.L., 2002, 'Implications of tuberculosis in African wildlife and livestock', *Annals of the New York Academy of Sciences* 969, 251–255. http://dx.doi.org/10.1111/j.1749-6632.2002.tb04387.x, PMid:12381600

Michel, A.L., Bengis, R.G., Keet, D., Hofmeyr, M., Klerk, L.M.D., Cross, P.C. *et al*., 2006, 'Wildlife tuberculosis in South African conservation areas: Implications and challenges', *Veterinary Microbiology* 112(2-4), 91–100. http://dx.doi.org/10.1016/j.vetmic.2005.11.035, PMid:16343819

Michel, A., Coetzee, M., Keet, D., Maré, L., Warren, R., Cooper, D. *et al*., 2009, 'Molecular epidemiology of *Mycobacterium bovis* isolates from free-ranging wildlife in South African game reserves', *Veterinary Microbiology* 133(4), 335–343. http://dx.doi.org/10.1016/j.vetmic.2008.07.023, PMid:18786785

Montali, R.J., Mikota, S. & Cheng, L., 2001, '*Mycobacterium tuberculosis* in zoo and wildlife species', *Revue scientifique et technique – Office International des Épizooties* 20(1), 291. PMid:11288517

Mwenye, K., Sizia, S. & Peterson, D., 1996, 'Factors associated with human anthrax outbreak in the Chikupo and Ngandu villages of Murewa district in Mashonaland East province, Zimbabwe', *The Central African Journal of Medicine* 42(11), 312. PMid:9130412

Oberem, P. & Oberem, P., 2011, *A guide to animal diseases in South Africa: Game,* Briza, Pretoria.

Ogden, N.H. & Tsao, J.I., 2009, 'Biodiversity and Lyme disease: Dilution or amplification?', *Epidemics* 1(3), 196–206. http://dx.doi.org/10.1016/j.epidem.2009.06.002, PMid:21352766

Oh, P., Granich, R., Scott, J., Sun, B., Joseph, M., Stringfield, C. *et al*., 2002, 'Human exposure following *Mycobacterium tuberculosis* infection of multiple animal species in a metropolitan zoo', *Emerging Infectious Diseases* 8(11), 1290. http://dx.doi.org/10.3201/eid0811.020302, PMid:12453358

Parra, A., García, A., Inglis, N., Tato, A., Alonso, J., Hermoso De Mendoza, M. *et al*., 2006, 'An epidemiological evaluation of *Mycobacterium bovis* infections in wild game animals of the Spanish Mediterranean ecosystem', *Research in Veterinary Science* 80(2), 140–146.

Paskin, R., 1999, *Manual on livestock disease surveillance and information systems,* FAO, Rome, viewed 09 May 2011, from http://www.fao.org

Paulsen, P. & Smulders, F.J.M., 2004, 'Infectious diseases of meat animals', in W.K. Jensen, C. Devine & M. Dikeman (eds.), *Encyclopaedia of Meat Sciences*, pp. 649–656, Elsevier Academic Press, London. http://dx.doi.org/10.1016/B0-12-464970-X/00024-6

Pavlin, B.I., Schloegel, L.M. & Daszak, P., 2009, 'Risk of importing zoonotic diseases through wildlife trade, United States', *Emerging Infectious Diseases* 15(11), 1721. PMid:19891857

Phillips, C.J.C., Foster, C.R.W., Morris, P.A. & Teverson, R., 2003, 'The transmission of *Mycobacterium bovis* infection to cattle', *Research in Veterinary Science* 74(1), 1–15. http://dx.doi.org/10.1016/S0034-5288(02)00145-5

Pozio, E., 2005, 'The broad spectrum of *Trichinella* hosts: From cold-to warm-blooded animals', *Veterinary Parasitology* 132(1-2), 3–11. http://dx.doi.org/10.1016/j.vetpar.2005.05.024, PMid:15970384

Pozio, E., Capelli, O., Marchesi, L., Valeri, P. & Rossi, P., 1988, 'Third outbreak of trichinellosis caused by consumption of horse meat in Italy', *Annales de parasitologie humaine et comparée* 63(1), 48. PMid:3041893

Radder, L. & Le Roux, R., 2005, 'Factors affecting food choice in relation to venison: A South African example', *Meat Science* 71(3), 583–589. http://dx.doi.org/10.1016/j.meatsci.2005.05.003, PMid:22060937

Red Meat and Research Development South Africa (RMRDSA), 2010, *ASF in soft tampans*, Research project, viewed 01 February 2012, from http://www.rmrdsa.co.za

Rupprecht, C.E. & Fekadu, M., 1995, 'The ascension of wildlife rabies: A cause for public health concern or intervention?', *Emerging Infectious Diseases* 1(4), 107–114. http://dx.doi.org/10.3201/eid0104.950401, PMid:8903179

Scoones, I., Bishi, A., Mapitse, N., Moerane, R., Penrith, M-L.P., Sibanda, R. *et al*., 2010, 'Foot-and-mouth disease and market access: Challenges for the beef industry in southern Africa', *Pastoralism* 1(2), 135–164.

Shanthikumar, S.R. & Atilola, M.A., 1990, 'Outbreaks of rinderpest in wild and domestic animals in Nigeria', *Veterinary Record* 126, 306–307. PMid:2343518

Shitaye, J.E., Tsegaye, W. & Pavlik, I., 2007, 'Bovine tuberculosis infection in animal and human populations in Ethiopia: A review', *Veterinarni Medicina* 52(8), 317–332.

Skinner, J., 1970, 'Game-ranching in Africa as a source of meat for local consumption and export', *Tropical Animal Health and Production* 2(3), 151–157. http://dx.doi.org/10.1007/BF02359682

Sleeman, J., 2006, 'Wildlife zoonoses for the veterinary practitioner', *Journal of Exotic Pet Medicine,* 15(1), 25–32. http://dx.doi.org/10.1053/j.jepm.2005.11.006

South African Government, 1984, '*Animal Diseases Act*, No. 35 of 1984', viewed 09 May 2011, from http://www.daff.gov.za

Swanepoel, R., Barnard, B., Meredith, C., Bishop, G., Brückner, G., Foggin, C. *et al*., 1993, 'Rabies in southern Africa', *Onderstepoort Journal of Veterinary Research* 60(4), 325.

Tambi, E., Mania, O.W., Mukhebi, A. & Randolph, T., 1999, 'Economic impact assessment of rinderpest control in Africa', *Revue scientifique et technique – Office International des Épizooties* 18(2), 458. PMid:10472679

Tarnoczi, T.J. & Berkes, F., 2010, 'Sources of information for farmers' adaptation practices in Canada's prairie agro-ecosystem', *Climatic Change* 98(1), 299–305. http://dx.doi.org/10.1007/s10584-009-9762-4

Taylor, J.P. & Perdue, J.N., 1989, 'The changing epidemiology of human brucellosis in Texas, 1977–1986', *American Journal of Epidemiology* 130(1), 160–165. PMid:2787107

Taylor, L.H., Latham, S.M. & Woolhouse, M.E., 2001, 'Risk factors for human disease emergence', *Philosophical Transactions of the Royal Society of London B Biological Sciences* 356, 983–989. http://dx.doi.org/10.1098/rstb.2001.0888, PMid:11516376

Thoen, C., Lobue, P. & De Kantor, I., 2006, 'The importance of *Mycobacterium bovis* as a zoonosis', *Veterinary Microbiology* 112(2), 339–345. http://dx.doi.org/10.1016/j.vetmic.2005.11.047, PMid:16387455

Thomson, G. & Penrith, M-L., 2011, 'Animal health policy, legislation and trade in beef in the five participating states of the Kavango-Zambezi transfrontier conservation area (KAZA TFCA)', Technical Report to the Wildlife Conservation Society's AHEAD Programme.

Thornton, P., Van de Steeg, J., Notenbaert, A. & Herrero, M., 2009, 'The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know', *Agricultural Systems* 101(3), 113–127. http://dx.doi.org/10.1016/j.agsy.2009.05.002

Ungerer, W., 2008, Personal interview, Deputy Director: Epidemiology, Directorate Veterinary Services, National Department of Agriculture, Forestry and Fisheries, Pretoria.

Van der Merwe, M., Bekker, J.L., Van der Merwe, P. & Michel, A., 2009, 'Cooking and drying as effective mechanisms in limiting the zoonotic effect of *Mycobacterium bovis* in beef', *Journal of the South African Veterinary Association* 80, 142–145. PMid:20169745

Van Wyk, I.C. & Boomker, J., 2011, 'Parasites of South African wildlife. XIX. The prevalence of helminths in some common antelopes, warthogs and a bushpig in the Limpopo province, South Africa', *Onderstepoort Journal of Veterinary Research* 78(1). http://dx.doi.org/10.4102/ojvr.v78i1.308

White, Jr, P., Baker, Jr, E., Roth, A., Williams, W. & Stephens, T., 1974, 'Brucellosis in a Virginia meat-packing plant', *Archives of Environmental Health* 28(5), 263. PMid:4821770

Whitehouse & Associates, 2011, 'Technical Report: Regulatory Environment for Animal Feeds in Zambia, Malawi, Mozambique, Zimbabwe, Namibia and Botswana', AECOM International Development, USAID/Southern Africa, Southern African Trade Hub, Gaborone, Botswana.

World Health Organization (WHO), 1994a, 'Report of WHO working group on zoonotic tuberculosis (*Mycobacterium bovis*), with the participation of FAO. June 14', Geneva, World Health Organization. Unpublished: who/cds/vph/94.137.

World Health Organization (WHO), 1994b, 'Zoonotic tuberculosis (*Mycobacterium bovis*), Memorandum from a WHO meeting (with the participation of the Food and Agriculture Organization', *Bulletin of the WHO* 72(6), 851–857.

World Health Organization (WHO), 2010, 'Rift Valley fever in South Africa – update, global alert and response (GAR)', 04 May 2010, viewed 16 September 2012, from http://www.who.int/csr/don/2010_05_12/en/index.html

World Organisation for Animal Health (OIE), 2005, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 14–16 February 2005', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2006a, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 20–23 February 2006', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2006b, 'Economic analysis: Prevention versus outbreak costs', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2007, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 12–15 February 2007', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2008a, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 28–31 January 2008', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2008b, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 26–29 January 2009', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2010a, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 1–4 February 2010', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2010b, 'Report of the meeting of the OIE working group on wildlife diseases, Paris, 12–10 October 2010', viewed 15 June 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2011a,'OIE listed diseases', viewed 07 May 2011, from http://www.oie.int

World Organisation for Animal Health (OIE), 2011b, 'Terrestrial Animal Health Code', viewed 07 May 2011, from http://www.oie.int

Zieger, U., Pandey, G., Kriek, N. & Cauldwell, A., 1998, 'Tuberculosis in Kafue lechwe (*Kobus leche kafuensis*) and in a bushbuck (*Tragelaphus scriptus*) on a game ranch in central province, Zambia', *Journal-South African veterinary association* 69, 98–101.

Zinsstag, J., Kazwala, R., Cadmus, I. & Ayanwale, L., 2008, '*Mycobacterium bovis* in Africa', in Mycobacterium bovis *infection in animals and humans*, pp. 199–210, Blackwell, Oxford. http://dx.doi.org/10.1002/9780470344538.ch19