Zoonoses: a potential obstacle to the growing wildlife industry of Namibia

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Zoonoses, which account for approximately 75% of emerging human infectious diseases worldwide, pose a re-emerging threat to public health. With an ever-increasing interrelationship between humans, livestock and wildlife species, the threat to human health will rise to unprecedented levels. Wildlife species contribute to the majority of emerging diseases; therefore, there is an urgent need to define control systems of zoonoses of wildlife origin but very little information exists. In this review, we examine prevalent zoonotic infections reported in Namibia between 1990 and 2009 and assess their potential impact on the growing wildlife industry. A wide spectrum of zoonotic diseases was confirmed in both livestock and wildlife species, with rabies and anthrax cases being over-represented and also showing the widest species distribution. Whilst vaccination and ante-mortem inspection against these diseases may curb infected livestock species from entering the human food chain, such practices are difficult to implement in free-ranging wildlife species. In this context, there is a need to improve existing control measures and/or develop novel and better interventional strategies to reduce the threat of this re-emerging global problem. This review provides the basis for initiating a multidisciplinary evidence-based approach to control zoonoses in countries with thriving wildlife and game farming.

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The global trade in wildlife has historically contributed to the emergence and spread of infectious diseases due to new host adaptation by pathogens, increased human susceptibility to disease, changing environments, intensification of the human–animal interface, movement of humans and animals across international borders, emerging anti-microbial resistance, and minimal pathogen surveillance that has precluded assessment of the health risks (1–5). Zoonotic diseases are transmitted from vertebrate animals to humans through direct or indirect exposure to live animals, their by-products or contaminated environments (6, 7). Although the conversion of wildlife habitats into arable land for crops, pastures and lodging camps can be viewed as the biggest driver of emerging and re-emerging zoonotic diseases associated with wildlife species, it is the ever increasing wildlife–human–domestic animal interface, including the consumption of game meat around the world that attracts recent concerns and challenges (5). Traditionally, most meat-borne disease outbreaks arise from improper food handling practices and consumption of undercooked meat. In many cases, the majority of pathogens contaminating carcasses at slaughter have been traced back to the farm of origin (8, 9). Thus, a snapshot of prevalent pathogenic organisms can be obtained by sampling farming environments, which might be a challenge when considering free-ranging wildlife species.

The wildlife industry of Namibia

A greater economic weight currently placed on the wildlife meat industry and the tourism sector in Namibia compared to livestock farming has led to the establishment of numerous managed wildlife conservancies and to the spiralling of game farming units on many private farmlands, including some rural areas. In some areas, ruminant wildlife species is reared in close proximity to livestock which potentially results in a spill-over of infections in...
either direction. About 15–25% of private farmland is used for commercial game rearing, primarily for ranching, leisure hunting, live game capture and wildlife viewing (10). The Namibian population estimates of food-producing wildlife species other than fish and forest-dwelling invertebrates has been reported at a minimum of 2 million (11, 12). In terms of percentages, the major wildlife species under current and future consideration for commercial game meat export are: springbok (Antidorcas marsupialis), gemsbok (Oryx gazella), kudu (Tragelaphus strepsiceros), mountain zebra (Equus zebra hartmannae) and red hartebeest (Alcelaphus buselaphus) (11). These species provide the bulk of game meat with gemsbok, the kudu and springbok contributing approximately two-thirds of the total game meat produced on freehold farms. In 2009, Gemsbok and Springbuck population estimates stood at 388,411 and 731,563 respectively (11). Between 2001 and 2005, approximately 4,300 tonnes of game meat were produced annually in Namibia (13). Recent years have witnessed a huge increase in the production and export of wildlife meat to Europe and South Africa to meet the demands of discerning, affluent consumers who prefer meat produced in a sustainable and eco-friendly environment, where ethical and safe harvesting methods safeguard wholesomeness and nutritional value (12, 14). Between 16,000 and 26,000 tonnes of game meat is produced annually in Namibian farmlands for regional and international export markets, local supply and for personal consumption. This also includes meat that is produced during trophy hunting (15). Indeed, 275 tonnes of game meat were exported to South Africa and the European Union between 2009 and 2011 (as recorded by registered game export establishments). In this year’s hunting season (April to August 2012), an average of 86 tonnes of game meat and game meat products are being exported monthly to South Africa, illustrating a booming wildlife meat industry in Namibia. Concurrent with the expansion of wildlife in Namibia is a decline in free range domestic animal farming, particularly sheep and cattle, resulting in some export abattoirs processing game meat during the wildlife hunting season using their under-utilised processing facilities (16). A clear worldwide demand for meat from species such as springbok, gemsbok, blesbok, eland, wildebeest and kudu exists and it is anticipated that this will continue to increase (14, 17, 18).

**Potential implications of zoonoses to the wildlife industry**

The impact of zoonoses on human and animal health and welfare cannot be emphasised enough. The growing world population requires more food, especially safe and wholesome sources of protein. As a result, food security and safety issues have taken centre-stage on the global platform – all geared to safeguard human health. Since some zoonoses are notifiable diseases, these consequently can impose a huge economic burden on farmers through compulsory slaughter, resulting in loss of access to export markets and the local meat industry. With ruminant wildlife species increasingly entering the human food chain, coupled with a thriving managed wildlife for tourism purposes in Namibia, it is prudent to examine the extent to which such diseases may affect this emerging industry.

Around 60% of all human pathogens are zoonoses that are equally harboured by domestic and wild animals (19). And of the emerging infectious diseases, 75% of these are zoonoses predominantly associated with wildlife animals (4), thus clearly highlighting an increasing threat arising from these animal species. As outlined above, Namibia’s thriving wildlife population is reared and slaughtered for both domestic and export markets, placing wildlife on a different platform from its traditional past. Because rearing and slaughter practices tend to differ from those of livestock species, concerns on meat safety have risen and inevitably these have presented a challenge to the existing regulatory framework of the meat industry. The aim of this article is to examine the potential zoonotic risks from wildlife and reared animals in Namibia as confirmed by laboratory investigations and documented literature findings during 1990-2009 to provide the basis for initiating a multi-disciplinary evidence-based approach to control such diseases.

**Data collection**

The criteria for including zoonotic zoonoses in this manuscript were based on laboratory investigations during 1990-2009 and literature findings. Factors such as potential public health importance, morbidity, mortality and disease burden in both domestic and wild animals were also considered. Information on food-borne- and non-food-related zoonoses was extracted from annual surveillance reports of the Directorate of Veterinary Services in Namibia generated between 1990 and 2009 – primarily by their Central Veterinary Laboratory (CVL). All notifiable diseases were confirmed by an appropriate laboratory test. The major notifiable diseases in Namibia include rabies, Rift Valley fever (RVF), anthrax, brucellosis, chlamydiosis (psittacosis), Johne’s disease, bovine tuberculosis and selected exotic diseases (20). Further confirmation of notifiable diseases is obtained from regional or international reference laboratories, including the Onderstepoort Veterinary Institute (South Africa) and Instituto Zooprofilattico Sperimentale della Italia in Teramo (Italy). Similarly, in cases of inconclusive results or when an approved diagnostic test is unavailable, samples are forwarded to the regional OIE reference laboratory in South Africa. The monitoring of salmonellosis, pathogenic *Escherichia coli*, campylobacteriosis and *Clostridium perfringens* infections is a requirement under
food law procedural notices of Namibia (21, 22). The Namibia Institute of Pathology (NIP), which provides laboratory services to the health delivery sector confirming all human cases, works closely with the National Institute of Communicable Diseases (NICD), a regional centre of excellence in infectious diseases for the African continent at large. Although the majority of diseases required laboratory confirmation, the diagnoses of echinococcosis, cysticercosis, dermatophytosis and sarcocystosis during the period under review were primarily based on clinical and pathological findings. For convenience, we classified these diseases according to the aetiological agent, highlighting those encountered at a higher frequency in wildlife species in each category.

**Viral diseases**

**Rabies**

Rabies is caused by a *Lyssavirus* belonging to the family *Rhabdoviridae* that targets the central nervous system (CNS) resulting in a rapidly progressive and fatal encephalomyelitis. Transmission from animals to humans is primarily through bites and contact with secretions—although bats have been implicated in relatively few cases (23, 24). Vampire bats are the reservoir hosts of rabies in the West Indies and some South American countries, but these have not been reported in Namibia. Rabies is notifiable in Namibia and has the widest geographical, domestic and wildlife species distribution in the entire Southern Africa Development Community (SADC) region, making it a serious threat to the public, in particular farmers and hunters. Increased sporadic outbreaks of rabies in dogs, bovines and wildlife are common in northern and central regions of Namibia where up to 96% of deaths have been reported in the kudu (*Tragelaphus strepsiceros*), jackal (*Canis mesomelas*), bat-eared fox (*Otocyon megalotis*) and lion (*Panthera leo*) (23, 25, 26). The jackal is the recognised reservoir of rabies in southern Africa which has been implicated in unusual epizootics in the kudu (*Tragelaphus strepsiceros*) with lions subsequently contracting the disease from the rabid kudu (23, 27, 28). Of particular significance, the seasonal variation of rabies has been linked to occurrences in dogs and domestic ruminants together with the seasonal reproductive pattern of black-backed jackals (29). This epidemiological pattern is yet to be fully exploited in the control of rabies. Current control strategies centre on the restriction of animal movements and compulsory vaccination of dogs. This is supported by legislation which stipulates the need for a valid permit for all animal movements and mandatory current vaccination record for dogs. Fortunately, rabies vaccination is free for dogs, cats and other carnivores in Namibia, thereby removing the cost barrier from all pet owners. Despite this, the species distribution of rabies between 1990 and 2009 in Namibia was widespread (Table 1). Not surprisingly, majority of rabies cases were recorded in communal areas where huge numbers of dogs freely roam leading to a rapid spread through uncontrolled bites and contact with infected secretions. Furthermore, compliance with vaccination is relatively poor owing to lack of awareness on the risks of rabies in the rural communities. As such, there is a need for the regulatory authorities to re-evaluate the effectiveness of current approaches to controlling rabies in Namibia. Initiatives are also required for controlling the disease in wildlife apart from movement restrictions and monitoring. The kudu and the jackal had the highest prevalence of

| Species/animal type | Number affected |
|---------------------|----------------|
| Dog                 | 1557           |
| Cattle              | 1439           |
| Kudu                | 429            |
| Jackal              | 351            |
| Goat                | 278            |
| Cat                 | 189            |
| Sheep               | 89             |
| Bat-eared fox        | 49             |
| Fauna (unknown)     | 45             |
| Horse               | 28             |
| Mongoose            | 26             |
| Donkey              | 24             |
| Honey badger        | 15             |
| Mouse               | 14             |
| Hyaena              | 13             |
| Eland               | 12             |
| Suricate            | 12             |
| Pig                 | 8              |
| Gemsbok             | 7              |
| Cheetah             | 6              |
| Oryx                | 5              |
| Squirrel            | 5              |
| Antelope            | 4              |
| AARD wolf           | 4              |
| Eland               | 3              |
| Giraffe             | 2              |
| Monkey              | 2              |
| Baboon              | 2              |
| Warthog             | 2              |
| Duker               | 3              |
| Springbok           | 1              |
| Rat                 | 1              |
| Hartebeest          | 1              |
| Skunk               | 1              |
| Wildebeest          | 1              |
| Lion                | 1              |

Table 1. Distribution of confirmed cases of rabies across species between year 1990 and 2009 in Namibia

Source: Ref. [26].
rabies, indicating the importance of the jackal in the transmission of rabies to wild ruminants. Considering the kudu as a food-producing wild animal, it would be prudent to prescribe a precautionary approach in harvesting this species. The need to devise novel approaches in controlling rabies in the wildlife population should therefore be a priority.

Rift Valley fever
Rift Valley fever (RVF) is an arthropod-borne disease in mammals and humans caused by a Phlebovirus of the 
*Buanyviridae* family (30). The disease is widespread in the southern African region, having been reported in South Africa, Namibia, Madagascar, Zimbabwe and Botswana in the last 3 years (31, 32). Lack of a well-established wild reservoir host complicates the epidemiology of this disease. Direct transmission from infected ruminants to naive hosts has been linked to *Aedes* spp and also a large number of potential vectors with a different bio-ecology (33). Nevertheless, the diagnosis of RVF was primarily based on serology which led to confirmation of the disease in humans, rhinoceros (Diceros bicornis) and lion (Panthera leo), including sheep and goats predisposed by a high level of parasitism (26, 34). Elsewhere, RVF has been reported in other wildlife species further suggesting the importance of this disease. In Kenya, 71.4% of buffaloes were positive for neutralising antibodies in Ijara district, 50% in Nakuru district, 37.5 % in Nairobi and Laikipia districts and 22.6% in Tana River districts, suggesting buffaloes to be a highly susceptible host. High levels of RVF viral antibodies were also reported in the Zimbabwean black rhino (Diceros bicornis), white rhino (Ceratotherium simum), buffalo, waterbuck (Kobus ellip-
sipyrrymus) and the Kruger National Park African buffalo (35–37). Although the likelihood of a spill over of infection from either animal species exists, the author was unable to detect the virus by PCR in springbok (n =112) reared in close proximity to domestic animals with a history of RVF outbreaks. Direct exposure to infected animal secretions is associated with human mortality from RVF infection. In Namibia, periodic outbreaks of RVF often result in significant losses of livestock but the potential dangers of the disease to humans have only been realised in the past few years, necessitating a compulsory vaccination in all high risk areas (26). This exercise has been facilitated by the provision of free vaccination by the State to all high risk farms, particularly poor farmers in marginalised areas. As a result, every farmer is required to provide evidence of vaccination to a state veterinarian upon demand to ascertain compliance. Whilst implementation of such vaccination programmes appears relatively straightforward in domestic animals, application of similar programmes in free-ranging wildlife animals may be an insurmountable task. With the possibility of a spillover from domestic to wild animals and vice versa still existing, there is a need to explore the implementation of novel effective control strategies in both species.

Crimean-Congo hemorrhagic fever
Crimean-Congo hemorrhagic fever (CCHF) caused by a Nairovirus of *Bunyaviridae* family (38) inflicts a high mortality rate in humans (39). The virus is transmitted by Argasid or Ixodid ticks belonging to the genus *Hyalomma* and the worldwide distribution closely matches that of its main arthropod vector (40). CCHF is a public health concern worldwide due to its high fatality rate and also its preponderance to be transmitted nosocomially (40, 41). Ticks acquire CCHFV when feeding on viraemic animals (42) with small vertebrates, such as hares and hedgehogs, acting as amplifying hosts (43). The disease has been reported in a wide variety of wild animals; giraffe (*Giraffa camelopardalis*), rhinoceros (*Ceratotherium simum* and Diceros bicornis), eland (*Taurotragus oryx*), buffalos (*Syncerus caffer*), Burchell’s zebra (*Equus burchelli*), gemsbok (*Oryx gazella*) and greater kudu (*Tragelaphus strepsiceros*), wild carnivores, primates, smaller antelopes, pigs, blue wildebeest (*Connochaetes taurus*) and ostriches (44, 45). In humans, the disease is primarily an occupational hazard being reported more in shepherds, abattoir and leather factory workers, veterinary doctors, farmers, health personnel, soldiers, peasants, forest workers and hunters but rarely in picnic-goers and people involved in open-space activities (39, 40, 46). In Namibia, relatively few cases of CCHF have been reported in livestock farmers, but there is a lack of comprehensive or detailed investigation into the prevalence of the disease and its transmission pathways to humans in affected farming communities. Despite this, the wide host spectrum makes CCHF a major threat to humans, domestic and wildlife animals alike and, therefore, calls for an urgent review of current precautionary and control approaches.

Bacterial diseases

**Anthrax**

Anthrax is caused by a Gram-positive, sporulating bacterium, *Bacillus anthracis* and primarily affects all warm blooded animals, including herbivorous livestock and wildlife species (47). After rabies, anthrax has the second highest number of cases and widest geographical, domestic and wildlife species distribution in Namibia (Fig. 1). Transmission is usually via direct contact with infected material, inhalation of spores, ingestion of contaminated feed or water and, in rare cases, via blood-sucking insects. Characteristically, animals are often found dead due to overwhelming bacteraemia and toxemia. During this phase, the bacterium exists in a vegetative form which quickly sporulates upon exposure to air resulting in resistant spores that can survive in
the soil for up to 50 years. Due to this, post-mortem examination of anthrax cases is contra-indicated and carcasses are usually incinerated or buried whole. In Namibia, this is a notifiable disease and control is enforced by a regulatory requirement for annual vaccinations for all cattle with voluntary vaccination extended to sheep and goats. Furthermore, imported cattle older than 3 months are vaccinated every 12 months. We presume this to contribute significantly to the relatively low incidences observed in domestic animals compared to wildlife species (Fig. 1). Whilst implementation of such control practices is feasible in livestock species, there is a need to re-think on the modalities of applying these strategies in free-ranging wildlife species. Carcasses, resulting from peracute infection, are often detected after scavenger activity that litters the environment with spores, making it difficult to contain the infection (48). Moreover, contamination of environment with spores significantly contributes to perpetuation of the infection within the wildlife environment and therefore the population. Relatively high sero-prevalence rates among carnivores and to a lesser extent herbivores were reported, implying a regular non-fatal exposure in these wild animal species. Indeed, anthrax is endemic in Etosha National Park of Namibia, where fatal cases have frequently been detected in red hartebeest (Alcelaphus buselaphus), wildebeest (Connochaetes taurinus), zebra (Equus burchellii), springbok (Antidorcas marsupialis), eland (Tragelaphus oryx), giraffe (Giraffa camelopardalis), ostrich (Struthio camelus), white-backed vulture (Gyps africanus), chacma baboon (Papio ursinus) and polecat (Ictonyx striatus) (39, 40, 49). Of the herbivores, zebra (Equus burchellii), elephant (Loxodonta africana), wildebeest (Connochaetes taurinus), springbok (Antidorcas marsupialis) and buffalo contributed 97% of the cases in the period under review (25). Elsewhere, anthrax has been reported in wildlife in the Serengeti (Tanzania) (50) and the Kruger National Park (South Africa; 51). The detection of B. anthracis in 3.3% of the water samples and 3% of soil samples collected at different times of the year from 23 sites not associated with anthrax, confirmed persistent environmental contamination with bacterial spores (52). High prevalence rates (>50%) were found in faeces of scavengers (vulture, jackal and hyaena) collected within the vicinity of confirmed anthrax cases and 26% of water samples from associated national park waterholes were positive for anthrax organisms (52). Predation is a common method of transmitting anthrax to carnivores as seen in the cheetah (Acinonyx jubatus) whose source of infection is often the baboon (Papio ursinus) or red hartebeest (Alcelaphus buselaphus) (53, 54). On the contrary, exposure patterns in dogs have reflected known patterns of endemcity and in some cases provided new information about anthrax in the ecosystem, suggesting the potential of carnivores to be indicators of the disease (55). While species-specific ecological factors may affect anthrax

![Species distribution of anthrax cases across domestic and wildlife recorded between year 1990 and 2009 in Namibia (single numbered animals are not visible on the graph. Source: Ref. [26].](image-url)
exposure processes in Namibia, transmission cycles in different host species are still highly interrelated. Apart from restricting domestic animal movements within the national parks, there seems to be a lack of an effective strategy to control anthrax in the wildlife population, therefore calling for an exploration of new intervention approaches across southern Africa.

**Brucellosis**

Brucellosis in Bovine, Ovine and Caprine species has been reported at low incidences in Namibia (26). To date, no seropositive cases have been reported in free-ranging species of wild animals in Namibia. We recently screened 900 springbok (*Antidorcas marsupialis*) from 29 mixed farming units and found no serological evidence of brucellosis in these species (56). *Brucella spp* have been reported in the African buffalo (*Syncerus caffer*), mountain zebra (*Equus zebra*), waterbuck (*Kobus ellipsiprymnus*), hippopotamus (*Hippopotamus amphibious*), puku antelope (*Kobus vardoni*), wildebeest (*Connochaetes taurinus*), buffalo (*Syncerus caffer*), feral pigs, bushbuck (*Tragelaphus scriptus*), Burchell’s zebra (*Equus burchelli*), impala (*Aepyceros melampus*), eland antelope (*Taurotragus oryx*) and other wildlife species in SADC countries and elsewhere (57–60). Sero-prevalences of 23 and 48% were reported in African buffalo populations in The Kruger National Park and Zimbabwe, respectively, in the absence of direct contact with domestic animals (57). Although *B. melitensis* has been rarely reported in wildlife, it is endemic in the Kafue lechwe (*Kobus leche spp kafuensis*) reared at the wildlife–domestic animal interface in Zambia (61). Isolated cases have also been reported in *Rupicapura rupicapra* and *Capra ibex* in Europe (62). The incidence of brucellosis in domestic animals is often governed by the transmission dynamics (epidemiology), especially in extensive production systems where large herds may offer optimal conditions (60).

However, it is unclear why a relatively higher incidence was obtained in cattle than other domestic animals (Fig. 2). There is a regulatory requirement for all heifers aged 3–11 months to be vaccinated against brucellosis, whereas sheep and goats are vaccinated on a voluntary basis. In addition, all imported animals are pre-screened against brucellosis prior to and upon arrival. Brucellosis is one of the highly regulated diseases in Namibia where millions of dollars are spent annually on surveillance in both wildlife and domestic animals. Vaccination coverage data in small stock is currently unknown and farmers receive an automatic on-farm *Brucella* status upon generation of a movement permit from the Namibia Livestock Identification and Traceability System (NAM-LITS). In very few isolated caprine cases, the disease has been confirmed by bacterial isolation. On the other hand, the use of serological tests has been frequently complicated by the specificity of the tests, particularly arising from the effect of uncontrolled vaccinations with Rev.1 vaccine strain. The Complement Fixation Test (CFT) and Rose Bengal Test (RBT), in particular, have low specificity when testing sera from small ruminants vaccinated subcutaneously with Rev.1 strain, which can be improved when the vaccine is administered via the conjunctival route (63). The possibility of false positive serological reactions (FPSR) due to sharing of antigenic determinants with other Gram-negative bacteria, especially *Y. enterocolitica* O: 9 (64), should always be considered in all sero-positive cases.

**Salmonellosis**

Non-typhoidal salmonellosis represents an important human and animal disease of worldwide importance. There are over 2,000 *Salmonella* serovars, which all have the potential to cause illnesses in humans and animals despite certain serovars (*S. Typhimurium, S. Enteritidis* and *S. Newport*) being commonly implicated in human infections and *S. Dublin* and *S. Onderstepoort* more commonly associated with cattle and sheep, respectively, in South Africa (65–67). It is interesting to note that some serovars are associated with infections in crocodiles (*Crocodylidae*) (44). Forty-five *Salmonella* serovars were isolated from fish meal, fresh red meat (beef and lamb), cattle feedlot, and meat and bone meal samples in Namibia. A wide distribution of salmonellosis cases was observed in Namibia (Fig. 3), with cattle and ostriches topping the list. Although a few records were collected in elephants, the role in transmission could be associated with contamination of the environment and water sources.

**Campylobacteriosis**

*Campylobacter spp* cause one of the most common bacterial food-borne infections in some parts of the world (68, 69). The bacteria normally inhabits the intestinal tract of warm-blooded animals, such as poultry and cattle, and are frequently detected in foods derived from these sources.

![Fig. 2. Distribution of brucellosis across domestic species confirmed between year 1990 and 2009 in Namibia. Source: Ref. [26].](image-url)
animals (70). Despite 60–80% of cases of campylobacteriosis being attributed to chicken (69), none has been recorded in chickens in Namibia (Fig. 4), mainly because *Campylobacter* spp rarely cause pathology in this species, often regarded as a commensal that causes severe gastroenteritis in humans. In particular, *C. jejuni* primarily colonises the chicken gut and is excreted in high numbers in faeces without adverse symptoms (69). Campylobacteriosis in sheep and goats, caused by *Campylobacter fetus* ssp. *fetus intestinalis*, is of less zoonotic importance compared to *C. jejuni* and *C. coli* (71, 72). Although the prevalence of *C. jejuni* and *C. coli* in sheep at slaughter was reported to be 44 and 17%, respectively, compared to 24% in cattle and 94% in pigs, there is little evidence to suggest that red meat and wild game species present a risk to human infections (71). Relatively little work has been done on zoonotic *Campylobacter* spp in Namibia as reflected by the very few cases recorded (Fig. 4).

**Escherichia coli infections**
Pathogenic *Escherichia coli* strains have been a major concern in the meat industry for decades (60). Among these, Shiga toxin-producing *E. coli* (STEC) which are harboured in the intestinal tracts of ruminants still present a major public health concern. Although STEC O157:H7 was associated with several outbreaks since its first report in 1983, non-O157 strains are increasingly being encountered in recent years, now accounting for 20–70% of STEC infections throughout the world. Of the 81 different non-O157 serogroups associated with shiga toxins’ presence, 71% of these were represented by six serogroups; O26, O45, O111, O103, O121 and O145 (73–76). Direct or indirect contact with ruminant faeces is the leading antecedent to STEC infections in humans (77). Principal virulence factors associated with these strains are either plasmid borne or phage encoded, increasing the likelihood of a spontaneous horizontal gene transfer between species or serotypes. Moreover, the occurrence of stx-phages as free infectious particles in the environment and their persistence in water systems contribute to a high dispersal rate of these virulence genes (78). There is relatively very little work done on STEC in Namibia and factors affecting meat safety policy include lack of laboratories offering *E. coli* serotyping, insufficient risk assessment data and lack of updated food laws. Performance standards of slaughtering process of both domestic and wildlife species are usually based on *Enterobacteriaceae*, generic *E. coli* and generic *Salmonella* levels (79). Although not confirmed by the culture method, *E. coli* O157:H7 had...
previously been isolated in eight out of 95 meat samples using Polymerase chain reaction (PCR) in Namibia. Prompted by high Enterobacteriaceae counts in five batches of springbok meat, we undertook a limited survey to determine the prevalence of STEC in rectal contents and found none (80). As such, a comprehensive survey is therefore required to define the role of wildlife ruminants in the epidemiology of STEC to inform on aspects of meat safety.

**Chlamydiosis**

*Chlamydiaceae* are Gram-negative obligate intracellular bacteria that primarily replicate in mucosal epithelial cells of the conjunctiva, the respiratory, urogenital and gastrointestinal tract and are responsible for a broad range of diseases in animals and humans (81). The genus *Chlamydia* includes *C. trachomatis* (humans), *C. suis* (swine) and based on morphological characters and 16S rRNA and 23S rRNA gene sequences, the genus *Chlamydophila* includes *C. psittaci* (avian), *C. felis* (cat), *C. abortus* (sheep, goat and cattle), *C. caviae* (guinea-pig), the former species *C. pecorum* (sheep and cattle) and *C. pneumonia* (humans) (32, 82). Previous work in Namibia indicated that *C. abortus* infections were prevalent in all the geographical regions tested with on-farm and individual sero-prevalence levels in goats ranging between 8 and 50% (83, 84). Among the domestic animals, goats were over-represented (Fig. 5). In wild ungulates, sero-prevalence rates ranging from 23 to 60% were reported in European wild boar, red deer, fallow deer, roe deer, mouflon, barbary sheep, Southern chamois and Iberian ibex (85). Chlamydiosis is also widespread in Nile crocodiles (*Crocodylus niloticus*) on Zimbabwean farms although the danger of zoonotic transfer is not yet known (44). The possibility of transmission from livestock to free-living bird species has been confirmed using selected species: *Chlamydia suis*, *Chlamydia muridarum* and *Chlamydophila abortus* (86). Although no conclusive data on the prevalence and relevance of chlamydiae in wild mammals are available in Namibia, there are a few unreported studies on the prevalence of *Chlamydophila abortus* in targeted wildlife species. More studies are therefore required to provide the basis of implementing effective control strategies. Nevertheless, in-depth integrated intervention strategies can also be carried out based on available data of *C. psittaci* and *C. abortus* in domestic animals, as shown in Fig. 5.

**Clostridial infections**

*Clostridium perfringens* type A and *Clostridium difficile* food poisoning are among the most commonly identified and hypothesized food-borne illnesses typically transmitted via improper handling of contaminated foods (http://www.ncbi.nlm.nih.gov/pubmed/20642351). Type C of *Clostridium botulinum* intoxications have been reported in 117 species of feral birds and a wide variety of mammalian species (http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/205400.htm). Vaccination of domestic animals especially cattle, sheep and goats against clostridial diseases is one of the most extensively practiced preventative measure in Namibian farming community. Despite the vaccinations, cases of *Cl. Tetani* and

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*Fig. 5. Cases of chlamydiosis and/or psittacosis in domestic species recorded between year 1990 and 2009. Source: Ref. [26].*
C. botulinum were recorded every year (Table 2) possibly resulting from insufficient vaccination coverage, vaccine failure or seasonal mineral deficiency (like phosphate) in grazing environments. To date, no cases of C. difficile have been recorded in Namibia.

Parasitic diseases

Echinococcosis

Echinococcus granulosus is a tapeworm with nine genotypes which inhabits the small intestine of canines, whereas E. multilocularis infects foxes, raccoons, small rodents (definitive hosts) with dogs and cats acting as accidental hosts (69). Adult E. granulosus worms occur in large numbers in the small intestine of many wild animals, including hyaena, lion, wild dog (Lycaon pictus) and leopard. Echinococcosis is commonly encountered in free-ranging Burchell’s zebra, buffalo, greater kudu, and hippopotamus, and impala may serve as intermediate hosts (44). In Namibia, hydatid cyst of Echinococcus granulosus has been reported in giraffes (Giraffa camelopardalis) (87) and is commonly reported in livestock species.

Trichinellosis

Trichinella is one of the world’s most widely distributed food-borne zoonotic nematode of mammals, birds and reptiles (88). Natural infection with Trichinella spp. has been described in more than 150 mammalian species (89) but there are few reports in wildlife species emanating from Africa. Noteworthy, Trichinella nelsoni and T. spiralis were found in wild game in South Africa (20) whilst T. zimbabwensis was first described in southern African monitor lizards (Varanus niloticus) and Nile crocodiles (88, 90). With a wide species distribution, including monitor lizards, wild pigs, domestic pigs, wild zebra and crocodiles, the risk of transmission is relatively high. Although, the incidences of Trichinella spp. in domestic and/or wildlife is still limited to Namibia, Trichinella genotype T8 has been detected in a lion and larvae have been found in a spotted hyena and a black-backed jackal from Etosha National Park (88). The prevalence of T. zimbabwensis in Namibian wild crocodiles and in their predators remains unknown; however, the natural distribution of T. zimbabwensis in South African wild crocodiles includes all the major river systems in the Kruger National Park where T. zimbabwensis occurs in 10 out of every 12 culled crocodiles (91). Recent years have witnessed a rapid expansion of the crocodile industry in Namibia and some of these are often preyed upon by leopards (92).

Cysticercosis

Worldwide, human cysticercosis is a major public health concern with T. saginata and T. solium being frequently associated with cattle and swine, respectively (93, 94). The parasite is common in wildlife and domestic species (95). Clinical diagnosis is often difficult and confirmation is usually at post-mortem, suggesting this disease could possibly be under-diagnosed. In South Africa, cysticercosis appears to be most prevalent in the Eastern Cape Province, where pigs roam freely and sanitation facilities are inadequate or non-existent (20). Segments of tapeworms often feature as an ingredient of concoctions prepared by traditional healers and are suspected to be sources of many of the cases of cysticercosis in South Africa (20, 96). In Namibia, 865 bovine and five sheep carcasses were detained for cysticerci during meat inspection at six export abattoirs. Infestation has also been reported in impala, buffalo and blue wildebeest (36). Despite the high prevalence (97) of cysticercosis in Namibian livestock, the disease is not regarded as reportable, hence data on the burden in humans is lacking for most regions. Preventative approaches against taeniasis and cysticercosis need to be re-evaluated, especially at primary production level, that is, communal and commercial farming areas. A holistic approach involving key sectors like the Ministry of Health and Social Services is also required to improve early detection and control of this disease.

Rickettsial diseases

Coxiella burnetti (Q fever)

Q fever is a tick-transmitted zoonosis caused by Coxiella burnetti (98) with a worldwide distribution and a potential to infect most vertebrate species, including humans, ruminants, rodents, cats and reptiles (69). The traditional reservoirs of infection are domestic animals: cattle, sheep and goats, with parturient domestic cats and dogs implicated as sources of outbreaks (99). In Namibia, most cases were recorded in caprine species, but there is...
lack of documented evidence of this infection in wild animals. As such, the potential risk to public health remains highly likely but is unknown.

Fungal diseases

Dermatophytosis (Ringworm)
Ringworm is caused by different species of dermatophytes with the zoophilic species: *Microsporum canis*, *Trichophyton verrucosum* and *T. mentagrophytes* predominantly associated with wild and domestic animals depending on the geographic region (100). Ringworm is routinely diagnosed in Namibian cattle; however, to date no cases have been reported for wildlife.

Other bacterial and parasitic diseases

Many diseases tend to pose a zoonotic threat directly or indirectly through consumption of livestock products, including wildlife (Fig. 6). Importantly, sarcocystisosis is a zoonotic disease caused by *Sarcocystis spp*, one of the most commonly found parasites in domestic animals worldwide (101). It is a cyst-forming coccidian parasite with obligatory two host life cycles involving carnivores as definitive hosts and herbivores or omnivores as intermediate hosts (102). The cysts have been reported in many domestic and wild animals, including rat, moon rat, bandicoot, slow loris, buffalo, monkey and man. The known definitive hosts for some species of *Sarcocystis* are: the domestic cat, dog and the reticulated python (103–106). Although a few cases have been reported in Namibian in sheep and lion (*Panthera leo*) at post-mortem, the infection is probably under-diagnosed (26, 107).

Johnne’s disease is caused by *Mycobacterium avium subsp. paratuberculosis* (MAP) (108). Recently, this bacterium has received an increasingly wide interest because of a rapidly growing body of scientific evidence which suggests a possible link between MAP and Crohn’s disease, a human inflammatory bowel disease (109). MAP is a potential human food-borne pathogen which is excreted in milk and survives current pasteurisation treatments (110, 111). Though a potential of wide host species exist, only a few cases were recorded in Namibian cattle.

Leptospirosis is an infectious zoonotic disease caused by spirochetal pathogenic *Leptospira species* of which *L. icterohaemorrhagiae* is the main serovar responsible for human disease (112). A variety of wildlife, including raccoons, white tailed deer, striped skunks, opossums, and red and grey foxes have been shown to harbour some *Leptospira* serovars (113) but very few cases have been recorded in Namibia.

*Toxoplasma gondii* is a protozoan parasite affecting all warm-blooded hosts worldwide (114). Relatively, little is known about the prevalence of *T. gondii* in Africa although a prevalence rate of 9% in the San (Bushmen)
people of Namibia and Botswana compared to 30% in the Indian and black communities of KwaZulu-Natal province of South Africa have been reported (20, 115). The parasite multiplies in the gastrointestinal tract of cats. Other mammals like captive carnivores, captive herbivores, free-living carnivores, free-living herbivores, moose (Alces alces), black bears (Ursus americanus), caribou (Rangifer tarandus), wolves (Canis lupus), mice (Mus musculus and Peromyscus spp), rats (Rattus norvegicus and Sigmodon hispidus), squirrels (Sciurus spp), rabbits (Sylvilagus floridanus), muskrats (Ondatra zibethicus), red foxes (Vulpes fulva), mink (Mustela vison), Burchell’s zebra, (Equus burchelli), hippopotamus (Hippopotamus amphibius), African elephant (Loxodonta africana), sand gazelle (Gazella subgutturosa marica), mountain gazelle (Gazella gazelle), the Dorcas gazelle (Gazella dorcas), defassa waterbuck (Kobus defassa), lion (Panthera leo) and rock hyrax (Procavia capensis) can become infected by ingesting food or water contaminated with oocysts (116–120).

Of the 27 species belonging to the genus Toxocara, the majority infect carnivores from the Canidae, Felidae, Viveridae, Procyonidae, Mustelidae and Herpestidae families (121). Toxocara vitulorum is mainly found in tropical and subtropical regions, where it is a common parasite affecting water buffalo, Zebu cattle, lions and spotted hyenas (Crocuta crocuta) and is considered a low-level zoonotic disease agent (122, 123). T. canis, T. cati and T. petropodis are the aetiological agents of human toxocariasis (121) but these have not yet been recorded in Namibia.

Mycobacterium bovis infects a wide range of hosts, including domestic livestock, wildlife and humans, and it has been reported in cattle, insectivores, rodents, feral Asian water buffalo (Bubalus bubalis), white tailed deer (Odocoileus virginianus), brushtail possum (Trichosurus vulpecula), ferret (Mustela furo), feral wild boar (Sus scrofa), African buffalos (Syncerus caffer), lions and lechwe (Kobus leche) (49–51, 123). The control of bovine tuberculosis and atypical mycobacterioses in developing countries is difficult because of the existence of wildlife reservoirs (50, 124). Over the past 20 years, no cases have been reported in Namibian cattle although insignificant numbers have been recorded in poultry and suricato. This is probably due to the effectiveness of the bovine tuberculosis eradication programme implemented by the Namibian regulatory authorities and the subsequent routine monitoring and testing of all dairy farms and imported animals before and when they enter the country.

Oocysts of Cryptosporidium and cysts of Giardia occur in the aquatic environment throughout the world. They have been found in most surface waters, where their concentration is related to the level of faecal pollution or human use of the water (125). The sporadic high counts of Giardia and Cryptosporidium in the Namibian raw water sources indicate that a multiple-barrier approach must be followed to ensure the safe operation of treatment plants using polluted source water (126). The role of wildlife in transmitting Giardia to humans has been controversial although a variety of Giardia species has been isolated from wild mammals, birds, amphibians and reptiles (127).

Swine erysipelas (SE) is a zoonotic disease caused by the bacterium Erysipelothrix rhusiopathiae which also causes a serious disease in domestic pigs and wild boars (128) in Namibia. However, human erysipelas is rare and limited to animal handlers.

Discussion and future perspectives

Illegal wildlife trade is estimated to be a multibillion-dollar business involving unlawful harvest and trade in live wildlife animals, thus imposing a significant threat of infection to humans and domestic and wild animals. Zoonotic diseases can potentially lead to severe poverty, hunger and a compromised global health through banned trade and travel restrictions. However, the economic impact and the extent to which zoonoses contribute to human illnesses and death in the Namibian population are unknown. Though no outbreaks have been reported in Namibia, the emerging zoonoses avian influenza and swine influenza have been given significant attention at the expense of endemic zoonotic diseases. As such, prevalent zoonotic infectious diseases are likely to be considerably under-diagnosed because of the disproportionate focus on the disease of importance.

Economic importance for farmers or the meat industry is considered as one of the most influential factors in developing national strategies, plans and setting priorities on specific zoonotic diseases in Namibia. To protect the domestic food-producing animals and their export markets, brucellosis, Bovine spongiform encephalopathy (BSE), tuberculosis, anthrax, rabies, RVF and avian influenza have been given much financial and regulatory attention. Recently, significant amounts of resources have been channelled for the control of rabies in companion animals and RVF in domestic food-producing animals due to outbreaks of the two diseases. In the developing world, 56 zoonotic diseases are responsible for approximately 2.5 billion cases of human illness and 2.7 million deaths annually. Recent studies in Africa and beyond indicate the importance of the most common 13 zoonotic diseases in terms of their impact on human deaths and effect on livestock in the descending order: zoonotic gastrointestinal disease, leptospirosis, cysticercosis, zoonotic tuberculosis, rabies, leishmaniasis, brucellosis, echinococcosis, toxoplasmosis, Q fever, zoonotic trypanosomiasis, hepatitis E and anthrax (129). When information on the 13 most common zoonotic diseases in the developing world is applied to Namibia, evidence
indicates a poorly defined national strategy and priority settings for nine of the diseases. In this regard, risk-based priority for monitoring and surveillance should be recommended for Namibia to facilitate directing efforts and resources to where they are most needed.

A wide spectrum of zoonotic diseases has been recorded primarily in domestic animal species and select wildlife species in Namibia over a 20-year period. With an increasing interaction between humans, domestic and wildlife, the threat of transmission of zoonotic diseases has never been so alarming. Wildlife species are well-documented reservoirs of many infectious diseases and evidence of transmission between domestic and such species exists. The preference of organically produced and highly nutritious game meat by today’s population further increases the risk of food-borne zoonoses. Game farming has become thriving business in Namibia’s arid regions, ranging from small-holder conservancies in rural areas to large commercial game ranches which slaughter for the export market. It is therefore imperative to examine the extent of this emerging/re-emerging threat posed by the rising interaction between humans and animals. By analysing such data, an evidence-based case can be formulated for a multidisciplinary approach to tackle such diseases within the framework of a ‘one health’ concept. It is worthy to appreciate that control of the zoonoses associated with food-producing domestic species can be implemented at any point along the food production continuum, but such a farm-to-fork approach may be difficult to apply in free-ranging wildlife species. Whilst this may be feasible for food-producing wild animals, this tends to be more difficult when dealing with wild carnivores.

Although, control of zoonoses may appear to be feasible in domestic species, evidence presented herewith shows a rising trend of certain diseases in domestic species, in particular rabies in the dog and cattle. However, the emergence of unusual and highly pathogenic serotypes or pathotypes as seen in the recent outbreak of haemorrhagic colitis and haemolytic uremic syndrome in or pathotypes as seen in the recent outbreak of haemor-


the emergence of unusual and highly pathogenic serotypes of E. coli and Shigella species, in particular rabies in the dog and cattle. However, the increasing worldwide threat of antimicrobial-resistant bacterial strains in particular methicillin-resistant Staphylococcus aureus (MRSA) and extended spectrum beta-lactamase (ESBLs) Enterobacteriaceae strains of animal origin require utmost attention. Thus, a multifaceted approach to control of each disease is required across all domestic and wild animals to curb transmission of such diseases to humans.

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References

1. Aguirre AA, Gardner AC, Marsh JC, Delgado SG, Limpus CJ, Nichols WJ. Hazards associated with the consumption of sea turtle meat and eggs: a review for health care workers and the general public. Ecohealth 2006; 3: 141–53.
2. Jori F, Munstermann S, Mokopasetso M, Etter E, Mhongoyo J, Nkgwe C, et al. Investigating zoonotic diseases at the wildlife livestock interface in the Okavango Delta and Chobe National Park; 2011. Available from: http://www.wcsahead.org/gltfca_march2011/day_17_jori_zoonotic_botswana.pdf [cited 4 March 2011].
3. Siembieda JL, Kock RA, McCracken TA, Newman SH. The role of wildlife in transboundary animal diseases. Anim Health Res Rev 2011; 12: 95–111.
4. Smith KM, Anthony SJ, Switzer WM, Epstein JH, Seimon T, Jia H, et al. Zoonotic viruses associated with illegally imported wildlife products. PLoS One 2012; 7: e29505.

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5. Cima G. Wildlife, trade, susceptibility amplify food risks. JAVMA. Available from: http://www.avma.org/onlnews/javma/feb12/120215a.asp [cited 1 February 2012].

6. Grace D, Jones B. Zoonoses (Project 1) wildlife/domestic livestock interactions. The International Livestock Research Institute, Nairobi & Royal Veterinary College, London; 2011. Available from: http://mahider.iris.org/bitstream/handle/10568/12457/DFID%20FINAL%202009-9-2011.pdf?Sequence_1 [cited 25 September 2011].

7. WHO. Zoonosis. Available from: http://www.who.int/foodsafety/zoonoses/en/ [cited April 2010].

8. Sofos JN, Geornaras I. Overview of current meat hygiene and safety risks and summary of recent studies on biofilms, and control of Escherichia coli O157:H7 in non-intact, and Listeria monocytogenes in ready-to-eat, meat products. Meat Sci 2010; 86: 2-14.

9. Soon JM, Chadd SA, Baines RN. Escherichia coli O157:H7 in cattle: on farm contamination and pre-slaughter control methods. Anim Health Res Rev 2011; 12: 197-211.

10. Turpie J, Barnes J, Glenn-Marie Lange GM, Martin R. The contribution of wildlife to sustainable natural resource utilization in Namibia: a review. Sustainability 2010; 2: 3479-99.

11. Laubscher J, Jooste A, Mbai S, Idsardi E. Market study for goat products and venison. Meat Board of Namibia report; 2007. Available from: http://www.namnic.com.na/ [cited 20 December 2007].

12. Hoffman LC, van Schalkwyk DL, McMillin KW, Witthuhn RC. The contribution of wildlife to sustainable natural resource utilization in Namibia: a review. Sustainability 2010; 2: 3479-99.

13. Loubser J. The economic value of Namibia’s protected area system: a case for increased investment. Available from:http://www.theeis.com/data/literature/guidelines%20for%20the%20harvesting%20of%20game%20meat%20export.pdf [cited November 2010].

14. Hoffman LC, van Schalkwyk DL, McMillin KW, Witthuhn RC. The contribution of wildlife to sustainable natural resource utilization in Namibia: a review. Sustainability 2010; 2: 3479-99.

15. Lindsey P. An analysis of game meat production and wildlife based land uses on freehold land in Namibia: links with food security. TRAFFIC East/Southern Africa, Harare, Zimbabwe; 2011. Available from: http://www.traffiec.jrc.ec.europa.eu/publication/11_An_Analysis_of_Game_Meat.pdf [cited 20 July 2011].

16. Van Schalkwyk DL. Investigation into selected parameters required to develop a sustainable Namibian game meat industry. PhD thesis, Stellenbosch University, Stellenbosch, South Africa, 2011.

17. Drury R. Hungry for success: urban consumer demand for wild animal products in Vietnam. Conservat Soc 2011; 9: 247-57.

18. Wild and Hunt. Vol. 17/6. Available from: www.wildlifehunt.co.za [cited June 2011].

19. Molyneux D, Hallaj Z, Keusch GT, McManus DP, Ngowi H, Cleaveland S, et al. Zoonoses and marginalised infectious diseases of poverty: where do we stand? Parasit Vectors 2011; 4: 106.

20. Joubert JJ, Evans AC. Current status of food-borne parasitic zoonoses in South Africa and Namibia. Southeast Asian J Trop Med Public Health 1997; 28: 7-10.

21. Kamwi J. Circular V18/2007 on USDA-FSIS regulatory requirements. contamination with microorganisms, process control verification and testing pathogen reduction standards. Namibia: Directorate of Veterinary services.

22. Kamwi J. Circular V3/2012 on Food Safety of foodstuffs applying the HACCP based principles hazard analysis and critical control points (HACCP) based procedures. Namibia: Directorate of Veterinary services.

23. Fooks AR, Mansfield K, McElhinney L, Hüsßhle O, Mettler F, Sabetta C, et al. A molecular epidemiological study of rabies epizootics in kudu (Tragelaphus strepsiceros) in Namibia. BMC Vet Res 2006; 2: 2.

24. Gibbons RV. Cryptogenic rabies, bats, and the question of aerosol transmission. Ann Emerg Med 2002; 39: 528-36.

25. Berry HH. Surveillance and control of anthrax and rabies in wild herbivores and carnivores in Namibia. Rev Sci Tech 1993; 12: 137-46.

26. Directorate of Veterinary Services (2011): Annual disease reports from 1980–2011. Windhoek, Namibia: Ministry of Agriculture, Water and Rural Development.

27. Barnard BI, Hassel RH. Rabies in kudus (Tragelaphus strepsiceros) in South West Africa/Namibia. J S Afr Vet Assoc 1981; 52: 309-14.

28. Hüsßhle OJ. Rabies in the kudu antelope (Tragelaphus strepsiceros). Rev Infect Dis 1988; 10: S629-33.

29. Courtin F, Carpenter TE, Paskin RD, Cheverly V, Pepin M, Plee L, Lancelot R. Rift valley fever – a threat for Europe? Euro Surveill 2010; 15: 19506.

30. Archer BN, Weyer J, Pawska J, Nkosi D, Leman P, Tint KS, et al. Outbreak of Rift Valley Fever affecting veterinarians and farmers in South Africa. S Afr Med J 2011; 101: 263-6.

31. OIE/WAHID. Animal health information. Available from: http://www.oie.int/wahis2/public/wahid.php?Countryinformation/ countrypage [cited 25 May 2012].

32. Lefèvre PC, Blancou J, Chermette R. Principales maladies-infectieuses et parasites du bétail. Europe et régions chaudes. Vol. 1. Lavoisier, editor. Generalités. Maladies virales. Londres, Paris, New York; 2003.

33. Joubert JJ, Prozesky OW, Lourens JG, van Straten AM, Theron JW, Swanevelder C, et al. Prevalence of hepatitis virus and some arbovirus infections in Kavango, Northern SWA/Namibia. S Afr Med J 1985; 67: 500-2.

34. Anderson EC, Rowe LW. The prevalence of antibody to the viruses of bovine virus diarrhea, bovine herpes virus 1, Rift Valley Fever, ephemerai fever and bleutoguen and to Leptos- pira sp in free-ranging wildlife in Zimbabwe. Epidemiol Infect 1998; 121: 441–9.

35. Evans A, Gakuya F, Pawska JT, Rostal M, Akolu L, Van Vuren PJ, et al. Prevalence of antibodies against Rift Valley Fever virus in Kenya. Epidemiol Infect 2008; 136: 1261-9.

36. La Beaud AD, Cross PC, Getz WM, Glinka R, Kinsel J, Kinsel G. Rift Valley fever virus infection in African buffalo (Syncerus caffer) herds in rural South Africa: evidence of inter-epidemic transmission. Am J Trop Med Hyg 2011; 84: 641–6.

37. Appanaanavar SB, Mishra B. An update on Crimean Congo hemorrhagic fever. J Glob Infect Dis 2011; 3: 285–92.

38. Yigit GK. An example of tick-Crimean Congo hemorrhagic fever (CCHF) in Eflani district, Karabuk, Turkey. Sci Res Essays 2011; 6: 2395.

39. Yigit GK. An example of tick-Crimean Congo hemorrhagic fever (CCHF) in Eflani district, Karabuk, Turkey. Sci Res Essays 2011; 6: 2395.

40. Flick G, Drexler J, Fair J, Muyembe J-J, Wolfe ND, Drosten C, et al. Reverse genetics for Crimean–Congo hemorrhagic fever virus. Nature 2003; 425: 5997.

41. Flick R, Flick K, Feldmann H, Elgh F. Reverse genetics for Crimean-Congo hemorrhagic fever virus. J Virol 2003; 77: 5997-6006.

42. Ozlem Terzi O, Sisman A, Canbaz S, Sisman Y. An evaluation of spatial distribution of Crimean-Congo hemorrhagic fever
with geographical information systems (GIS), in Samsun and Amasya region. JMPR 2011; 5: 584-54.

43. CFSPH. Crimean-Congo hemorrhagic fever; 2011. Available from: http://www.cfsph.iastate.edu/Factsheets/pdfs/crimean_congo_hemorrhagic_fever.pdf [cited 20 August 2009].

44. Bengis RG, Veary CM. Public health risks associated with the utilization of wildlife products in certain regions of Africa. Rev Sci Tech Off Int Epiz 1997; 16: 586-93.

45. Shepherd AJ, Swanepoel R, Shepherd SP, McCullivray GM, Searle LA. Antibody to Crimean-Congo haemorrhagic fever virus in wild mammals from southern Africa. Am Trop Med Hyg 1987; 36: 133-42.

46. Kisting D. Namibia: Congo Fever patient out of South Africa hospital. Available from: http://promedmail.chip.org/pipermail/promed-cafr/2010-August/000439.html [cited 2 August 2010].

47. Lembo T, Hampson K, Auty H, Beesley CA, Bessell P, Rackman C, et al. Serologic surveillance of anthrax in the Serengeti ecosystem, Tanzania, 1996-2009. Emerg Infect Dis 2011; 17: 387-94.

48. Foyle KL, Delahay RJ, Masegi G. Isolation of Mycobacterium bovis from a feral wild boar (Sus scrofa) in the UK. Vet Rec 2010; 166: 663-4.

49. Corner LA. The role of wild animal populations in the epidemiology of tuberculosis in domestic animals: how to assess the risk. Vet Microbiol 2006; 112: 303-12.

50. Durnez L, Katakweba A, Sadiki H, Katholi CR, Kazwala RR, Lindeque PM, Turnbull PC. Ecology and epidemiology of tuberculosis in domestic animals: how to assess the risk. Vet Microbiol 2006; 112: 303-12.

51. Cleaveland S, Mlgenga T, Kazwala RR, Michel A, Kaare MT, Jones SL, et al. Tuberculosis in Tanzanian wildlife. J Wildl Dis 2005; 41: 446-53.

52. Lindde PM, Turnbull PC. Ecology and epidemiology of anthrax in the Etoша National Park, Namibia. Onderstepoort J Vet Res 1994; 61: 71-83.

53. Good KM, Houser A, Arntzen L, Turnbull PCB. Naturally acquired anthrax antibodies in a cheetah (Acinonyx jubatus) in Botswana. J Wildl Dis 2008; 44: 721-3.

54. Jager HG, Booker IIH, Hiirschle OBJ. Anthrax in cheetahs (Acinonyx jubatus) in Namibia. J Wildl Dis 1990; 26: 423-4.

55. Turnbull PC, Doganay M, Lindde PM, Aggen B, McGaugh J. Serology and anthrax in humans, livestock and Etoша National Park wildlife. Epidemiol Infect 1992; 108: 299-313.

56. Magwedere K, Bishi A, Tijupara-Zaire G, Eberle G, Hemberger Y, Hoffmann LC, et al. Brucellosis in free living African Buffalo (Syncerus caffer): a serological survey. Onderstepoort J Vet Res 1981; 48: 133-4.

57. Massey PD, Polkinghorne BG, Durrheim DN, Lower T, Speare R. Blood, guts and knife cuts: reducing the risk of swine brucellosis in feral pig hunters in north-west New South Wales, Australia. Rural Remote Health 2011; 11: 1793.

58. Muma JB, Land A, Siamudaala VM, Munang’andu HM, Muyembe M, Matope G, et al. Serosurvey of Brucella spp. in domestic livestock in Zambia. J Wildlife Dis 2010; 46: 1063-9.

59. Muma JB, Samui KL, Siamudaala VM, Oloya J, Matope G, Omer MK, et al. Prevalence of antibodies to Brucella spp. and individual risk factors of infection in traditional cattle, goats and sheep reared in livestock-wildlife interface areas of Zambia. Trop Anim Health Prod 2006; 38: 195-206.

60. Garin-Bastuji B, Oudar J, Richard Y, Gastellu J. Isolation of Brucella melitensis biovar3 from a chamois (Rupicapra rupicapra) in the southern French Alps. J Wildl Dis 1990; 26: 116-8.

61. Food and Agricultural Organization. Brucella melitensis in Eurasia and the Middle East; 2007. Available from: www.fao.org/docrep/012/i402e/i402e00.pdf [cited 14 May 2009].

62. Mainar-Jaime RC, Muñoz PM, María J, de Miguel MJ, Grillo MJ, Marin CM, et al. Specificity dependence between serological tests for diagnosing bovine brucellosis in Brucella-free farms showing false positive serological reactions due to Yersinia enterocolitica O: 9. Can Vet J 2005; 46: 913-6.

63. Hoelzer K, Swift AIM, Wiedmann M. Animal contact as a source of human non-typhoidal salmonelllosis. Vet Res 2011; 42: 34.

64. WHO. The immunological basis for immunization series: module 20: Salmonella enterica serovar Typhi (typhoid) vaccines; 2011. Available from: http://libdoc.who.int/publications/2011/9789241502610/en.pdf [cited October 2011].

65. Center for Disease Communication. Estimates of food borne illness in the United States; 2011. Available from: http://www.cdc.gov/foodborneburden/trends-in-foodborne-illness.html [cited 19 April 2011].

66. Department of Environment, Food, Rural Affairs (2010): Zoonoses report. Available from: http://www.defra.gov.uk/publications/files/pb13627-zoonoses-report2010.pdf [cited 9 September 2011].

67. World Health Organization. Campylobacter Fact sheet No. 255; 2011. Available from: http://www.who.int/mediacentre/factsheets/fs255/en/index.html [cited October 2011].

68. Outfitter P. Contamination of animal products: the minimum pathogen dose required to initiate infection. Rev Sci Tech Off Int Epiz 1997; 16: 30-2.

69. Department of Environment, Food and Rural Affairs. Draft profile for Campylobacter. United Kingdom. Veterinary surveillance strategy. Available from: http://www.defra.gov.uk/animalanddiseases/vetsurveillance/profiles/campylobacter1.pdf [cited 2005].

70. World Health Organization. Zoonotic non-O157 Shiga toxin-producing Escherichia coli (STEC). Report of a WHO Scientific Working Group Meeting, 23 to 26 June 1998, Berlin, Germany. Available from: www.who.int/medicinedocuments/zoonoses/docs/who0009988.html [cited 26 June 1998].

71. Brooks JT, Sowers EG, Wells JG, Greene KD, Griffin PM, Hockstra RM, et al. Non-O157 Shiga toxin–producing Escherichia coli infections in the United States, 1983–2002. J Infect Dis 2005; 192: 1422-9.

72. Bettelheim KA. Non-O157 Shiga-toxin-producing Escherichia coli. The Lancet Infect Dis 2012; 12: 12.

73. Fratamico PM, Bagi LK, Cray WC Jr, Narang N, Yan X, Medina M, et al. Detection by multiplex real-time polymerase chain reaction assays and isolation of Shiga toxin–producing Escherichia coli serogroups O26, O45, O103, O111, O121, and O145 in ground beef. Foodborne Pathog Dis 2011; 8: 601-7.

74. Martin BJ. Deconstructing a lethal foodborne epidemic. N Engl J Med 2011; 365: 1833-6.
78. Muniesa M, Jofre J, Garcia-Aliaro C, Blanch AR. Occurrence of *Escherichia coli* O157:H7 and other enterohemorrhagic in the environment. Environ Sci Technol 2006; 40: 7141–9.

79. Lenaun H, Crowley H, O’Brien SB, Byrne C, Sweeney T, Sheridan JI. The potential use of chilling to control the growth of Enterobacteriaceae on porcine carcasses and the incidence of *E. coli* O157:H7 in pigs. J Appl Microbiol 2009; 106: 1512–20.

80. Magwedere K, Shilangale R, Mbulu RS, Hemberger Y, Hoffman LC, Dziva F. The microbiological quality and potential public health risks of export meat from Springbok (*Antidorcas marsupialis*) in Namibia. Meat Sci 2012. DOI: http://dx.doi.org/10.1016/j.meatsci.2012.08.007.

81. Schauß M, Vanrompay D. Chlamydiaceae infections in pigs. Vet Res 2011; 42: 29.

82. Chen DK, Zhao GH, Shang CC, Zhao YQ, Gao M, Fan GY, et al. Seroprevalence of chlamydial infection in dairy goats in Shaanxi Province, Northwestern China. Afr J Biotechnol 2012; 11: 1796–9.

83. Apel J, Huebschle OJ, Krauss H. Seroprevalence of Chlamydia psittaci-specific antibodies in small stock in Namibia – epidemiological study with an enzyme-linked immunosorbent assay (ELISA). J Vet Med B 2005; 52: 447–58.

84. Samkange A, Katsande TC, Tjipura-Zaire G, Crafford JE. Seroprevalence study of *Chlamydia abortus* infection in breeding goats on commercial farms in the Otavi Veterinary District, Northern Namibia, Onderstepoort. J Vet Res 2010; 77: 1–5.

85. Salinas J, Caro MR, Vicente J, Cuello F, Reyes-Garcia AR, Buendía AJ, et al. High prevalence of antibodies against *Chlamydiaceae* and *Chlamydophila* abortus in wild ungulates using two “in house” blocking-ELISA tests. Vet Microbiol 2009; 135: 46–53.

86. Lemus JA, Fargallo JA, Vergara P, Parejo D, Banda E. Natural cross chlamydial infection between livestock and free-living bird species. PLoS One 2010; 5: e13512.

87. Kreeck RC, Boomerik J, Penzhorn BL, Scheepers L. Internal parasites of giraffes (*Giraffa camelopardalis angolensis*) from Etosha National park in Namibia. J Wildl Dis 1990; 26: 395–7.

88. Pozio E. World distribution of *Trichinella* spp. infections in animals and humans. Vet Parasitol 2007; 149: 3–21.

89. Ribičić M, Gamble HR, Bolpe J, Scola J, Krivokapich S, Crass JD. Seroprevalence of *Trichinella* infection in breeding goats on commercial farms in the Otavi Veterinary District, Northern Namibia. Vet Parasitol 2010; 107: 37–80.

90. La Grange LJ, Marucci G, Pozio E. *Trichinella* zimbabwensis in wild Nile crocodiles (*Crocodylus niloticus*) of South Africa. Vet Parasitol 2009; 161: 89–91.

91. La Grange LJ, Govender D, Mukaratirwa S. The occurrence of *Trichinella zimbabwensis* in naturally infected wild crocodiles (*Crocodylus niloticus*) from the Kruger National Park, South Africa. J Helminthol 2012; 16: e1–6.

92. Anonymous. Namibian Sun. Crocodile farm earmarked for Caprivi. 2011. Available from: http://www.namibiansun.com/content/national-news/crocodile-farm-earmarked-for-caprivi [cited 20 May 2011].

93. Food and Safety Inspection Service USA. Parasites and foodborne illness: 2011. Available from: http://www.fsis.usda.gov/Factsheets/Parasites_and_Foodborne_Illness/index.asp#7 [cited 24 May 2011].

94. Praet N, Kanobana K, Kabwe C, Maketa V, Lukau P, Lutumba P, et al. Taenia solium cysticercosis in the Democratic Republic of Congo: how does pork trade affect the transmission of the parasite? PLoS Negl Trop Dis 2010; 4: e817.

95. Haridy FM, Ibrahim BB, Morsy TA, Ramadan NI. Human taeniasis and cysticercosis in slaughtered cattle, buffaloes and pigs in Egypt. J Egypt Soc Parasitol 1999; 29: 375–94.

96. Phiri IK, Ngowi H, Afonso S, Matenga E, Boa M, Mukurarawira S, et al. The emergence of *Taenia solium* cysticercosis in Eastern and southern Africa as a serious agricultural problem and public health risk. Acta Tropica 2003; 87: 13–23.

97. Shikongo-Kuvare LT. Development of risk communication strategies to improve control of *Cysticercus Bovis* in North Central Namibia. MSc thesis, University of Pretoria, 2007.

98. Raoult D, Mediannikov O, Fenollar F, Socolovschi C, Diatta G, Bassene H, et al. Coxiella burnetii in humans and ticks in rural Senegal. PLoS Negl Trop Dis 2009; 4: e654.

99. Frean J, Blumberg L, Cutland C. Q fever: the Southern African perspective. Annals of ACTM: An International Journal Of Tropical & Travel Medicine 2007; 8: 32. Available from: http://www.tropmed.org/publications/annals/annals8n2.pdf [cited December 2007].

100. Akbarmehr M. The prevalence of cattle ringworm in native dairy farms of Sarab city (East Azarbayzan province). Iran Afr J Microbiol Res 2011; 5: 1268–71.

101. Nourollahi Fard SR, Ashghari M, Nouri F. Survey of *Sarcocystis* infection in slaughtered cattle in Kerman, Iran. Trop Anim Health Prod 2009; 41: 1633–6.

102. Hamidinejat H, Jalali RMH, Nabavi L. Survey on *Sarcocystis* infection in slaughtered cattle in South West of Iran, emphasized on evaluation of squash in comparison with digestion method. J Anim Vet Adv 2010; 9: 1724–6.

103. Kan SP, Pathanathan R. Review of *sarcocystosis in Malaysia*. Southeast Asian J Trop Med Public Health 1991; 22: 129–34.

104. Latif BM, Al-Delemi JK, Mohammed BS, Al-Bayati SM, Al-Amiry AM. Prevalence of *Sarcocystis* spp. in meat-producing animals in Iraq. Vet Parasitol 1999; 84: 85–90.

105. Bwamgamo O, Ngatia TA, Richardson JD. *Sarcocystis*-like organisms in musculature of a domestic dog (*Canis familiaris*) and wild dogs (*Lycaon pictus*) in Kenya. Vet Parasitol 1993; 49: 201–5.

106. Latif B, Vellayan S, Omar E, Abdullah S, Mat Desa N. *Sarcocystosis among wild captive and zoo animals in Malaysia*. Korean J Parasitol 2010; 48: 213–7.

107. Kinsel MJ, Briggs MB, Venzke K, Forge O, Murnane RD. Gastric spiral bacteria and intramuscular sarcocysts in African lions from Namibia. J Wildl Dis 1998; 34: 317–24.

108. Singh AV, Singh SV, Singh PK, Sohal JS. Is *Mycobacterium avium subsp. paratuberculosis* the cause of *Johnne’s disease in animals*, a good candidate for *Crohn’s disease in man? Indian J Gastroenterol* 2010; 29: 53–8.

109. Uzoigwe JC, Khaita MR, Gibb PS. Epidemiological evidence for *Mycobacterium avium* subspecies paratuberculosis as a cause of *Crohn’s disease*. Epidemiol Infect 2007; 135: 1057–68.

110. Scaru AM, Bull TJ, Cannas S, Sanderson JD, Sechi LA, Dettori G, et al. *Mycobacterium avium* subsp. paratuberculosis, the cause of *Johnne’s disease in animals*, a good candidate for *Crohn’s disease in man? Indian J Gastroenterol* 2010; 29: 53–8.
113. Timoney JF, Kalimuthusamy N, Velineni S, Donahue JM, Artiushin SC, Fettinger MA. Unique genotype of Leptospira interrogans serovar Pomona type kennewicki is associated with equine abortion. Vet Microbiol 2011; 150: 349–53.

114. Dubey JP, Velmurugan G, Rajendran C, Yabsley M, Thomas NJ, Beckman KB, et al. Genetic characterization of Toxoplasma gondii in wildlife from North America revealed widespread and high prevalence of the fourth clonal type. Int J Parasitol 2011; 41: 1139–47.

115. Kistiah K, Barragan A, Winiecka-Krusnell J, Karstaedt A, Frean J. Seroprevalence of Toxoplasma gondii infection in HIV-positive and HIV-negative subjects in Gauteng, South Africa. South Afr J Epidemiol Infect 2011; 26: 225–8.

116. Riemann GP, Burridge MJ, Behymer DE, Franti CE. Toxoplasma gondii antibodies in free-living African mammals. J Wildl Dis 1975; 11: 529–33.

117. Bakal PM, Karstad L, In ‘T Veld N. Serologic evidence of toxoplasmosis in captive and free-living wild mammals in Kenya. J Wildl Dis 1980; 16: 559–64.

118. Mohammed OB, Hussein HS. 1994. Antibody prevalence of Toxoplasmosis in Arabian Gazelles and Oryx in Saudi Arabia. J Wildl Dis 1994; 30: 560–2.

119. Smith DD, Frenkel JK. Prevalence of antibodies to Toxoplasma gondii in wild mammals of Missouri and east central Kansas: biologic and ecologic considerations of transmission. J Wildl Dis 1995; 31: 15–21.

120. Zarnke RL, Dubey JP, Kwok OCH, Ver Hoef JM. Serologic survey for Toxoplasma gondii in selected wildlife species from Alaska. J Wildl Dis 2000; 36: 219–24.

121. Borecka A. The spread of nematodes from Toxocara genus in the world. Wiad Parazytol 2010; 56: 117–24.

122. Engh AL, Nelson KG, Peebles R, Hernandez AD, Hubbard KK, Holekamp KE. Coprologic survey of parasites of spotted hyenas (Crocuta crocuta) in the Masai Mara National Reserve, Kenya. J Wildl Dis 2003; 39: 224–7.

123. ALERT (Africa Lion and Environmental Research Trust). Endemic and epidemic diseases, viruses and parasites impacting lion (Panthera leo) populations. Available from: http://lionalert.org/documents/Disease_Impacting_Lions.pdf [cited 8 November 2011].

124. Gous TA, Williams MC. The pathology of tuberculosis caused by Mycobacterium tuberculosis in a herd of free ranging springbok (Antidorcas marsupialis). Onderstepoort J Vet Res 2009; 76: 419–41.

125. Budu-Amoako E, Greenwood SJ, Dixon BR, Barkema HW, McClure JT. Foodborne illness associated with Cryptosporidium and Giardia from livestock. J Food Prot 2011; 74: 1944–55.

126. Menge JG, Haarhoff J, König E, Mertens R, van der Merwe B. Occurrence and removal of Giardia and Cryptosporidium at the Goreangab Reclamation Plant. Wa Sci Technol 2002; 1: 97–106.

127. Erlandsen SL. Biotic transmission – is giardiasis a zoonosis? In: Thompson RCA, Reynolds JA, Lymbery AJ, eds. Giardia from molecules to disease. Wallingford, UK: CAB Int.; 1994, pp. 83–97.

128. Risco D, Llario PF, Velarde R, Garcia WL, Benitez JM, Garcia A, et al. Outbreak of swine erysipelas in a semi-intensive wild boar farm in Spain. Transbound Emerg Dis 2011; 58: 445–50.

129. Grace D. Mapping of poverty and likely zoonoses hotspots (ILRI; 2012). Available from: http://mahider.ilri.org/handle/10568/21161 [cited 5 July 2012].

130. Beutin L, Martin A. Outbreak of Shiga toxin-producing Escherichia coli (STEC) O104:H4 infection in Germany causes a paradigm shift with regard to human pathogenicity of STEC strains. J Food Prot 2012; 75: 408–18.

131. Thalwitzer S, Wachtler B, Robert N, Wibbelt G, Muller T, Lonzer J, et al. Seroprevalence to viral pathogens in free-ranging and captive cheetahs (Acinonyx jubatus) on Namibian farmland. Clin Vaccine Immunol 2010; 17: 185–94.

132. Katakweba AAS, Mulungu LS, Eiseb SJ, Mahlaba TA, Makundi RH, Massawe AW, et al. Prevalence of haemoparasites, leptospires and coccobacilli with potential for human infection in the blood of rodents and shrews from selected localities in Tanzania, Namibia and Swaziland. J Afr Zool 2012; 47(1): 119–27.

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