A review of captive exotic animal-linked zoonoses

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Abstract

Captive exotic animal-linked zoonoses are part of a major global emerging disease problem. Exotic animals are notably represented in the pet trade, zoos, and to a far lesser extent in circuses, with exotic pets being the primary concern. Combined, in the UK there may be approximately 42 million exotic pets (including fishes) in private homes, an unknown number in zoos, and in circuses less than 40 individuals. A wide range of species is involved, and a large and expanding array of potentially pathogenic agents. Sixty-one percent of human diseases have a potentially zoonotic origin and 75% of global emerging human diseases have a wild animal link.

Exotic pets in particular may represent a source of largely unrecognised and unrecorded microbes and macroparasites in the domestic environment. Pet markets constitute an especially high risk of infection and these risks are fundamentally uncontrollable. Future guidance may include advising against keeping exotic animals as pets unless excellent monitoring for diseases and essential husbandry practices are pursued. Zoos and circuses also involve zoonotic risks but may be relatively low because public visits and exposure are infrequent.

The prevalence of exotic animal-linked zoonoses in the UK is unknown. Many cases of zoonotic disease are probably misdiagnosed as other conditions and under-reporting in general is a likely major factor in under-ascertainment of cases. In addition, border and domestic biosecurity is lacking. New guidance on zoonoses monitoring, prevention and control is included as well as upgraded public health guidance that emphasises special caution against over-reliance on hand washing and other widely recommended measures.

Animal facilities should be required to provide independently sanctioned guidance on health risk and maintain strict record-keeping that includes detailed animal inventories, treatment data and post-mortem reports as well as pet purchaser details to assist in contact tracing in the event of outbreaks. Local authorities should also liaise with animal facilities to develop obligatory zoonotic disease response plans.

Key words: *Exotic pets, zoos, circuses, zoonoses, disease, prevention, control*

Introduction

Captive exotic animals are notably represented in the pet trade (and keeping) and in zoos, and to a far lesser extent in circuses. Combined, in the UK there may be approximately 42 million exotic pets (including fishes) in private homes, an unknown number in zoos, and less than 40 in circuses. Actual numbers are very difficult to accurately determine owing to the poor regulation of the market and the high animal death rates, in particular for the pet trade, and generally deficient inventory keeping for zoos. The prevalence of exotic animal-linked zoonoses in the UK is unknown. However, many cases of zoonotic disease are probably misdiagnosed as other conditions and under-reporting in general is a likely major factor in under-ascertainment of cases (Warwick, 2004).

Potential health threats from captive exotics probably vary according to captive context. For example, for exotic pets direct public contact with animals and their cages and other intermediary surfaces is common, whereas for zoo and circus animals public contact is less frequent.

Zoonoses, as defined by the World Health Organisation, includes "any disease or infection that is naturally transmissible from vertebrate animals to humans and vice-versa" (Anon., 2011). Some zoonoses have a long association with people. It is probable that for at least as long as humans have killed animals for food they have inadvertently contracted food-borne parasites. Since at least the Middle Ages 'the plague', tapeworm infestation and other zoonoses afflicted humans, as animals became our cohabitants either incidentally with rodents or deliberately with farmed species (Wilson and Sande, 2001; Hubálek and Rudolf, 2011).

Accordingly, zoonotic infections and infestations are not new, but today they form part of the phenomenon of emerging human diseases because they constitute a growing, and in many cases, novel health threat (Brown, 2003; Chomel *et al*., 2007; Wolfe *et al*., 2005; Zinsstag *et al*., 2007). This pathological renaissance is largely attributable to two factors, both of which can substantially be controlled. One factor is that the efficiency and economics of modern transportation offers humans convenient access to increasingly remote areas of the world – introducing people to novel environments within hours or days (Weber and Rutala, 2001; Brown, 2004). Another factor is that wild animal species are conveniently transported from distant regions of the world to the domestic market, in particular for pet purposes, again within a very short period of time.

A key difference between these two situations is that for foreign human travellers, adopting prophylactic measures is all part of responsible journeying. However, where importing exotic animals is concerned, public awareness of the potential threat they pose is very limited (Smith *et al*., 2010). Exotic pets, of course, will become a home feature and, for example, most, if not all, reptiles will be harbouring one or another potentially pathogenic agent (Warwick *et al*,. 2001; Mermin *et al*,. 2004). In effect, an exotic animal may harbour a raft of potentially infective microbes and macroparasites making any animal a possible Trojan Horse of infection and infestation (Warwick, 2006).

A survey of 1,410 human diseases found 61% to be of potentially zoonotic origin (Karesh *et al*., 2005). Also, 75% of global emerging human diseases have a wild animal link (Brown, 2004). Concern over modern zoonoses, often citing pets, has been voiced for decades, for example in Lamm *et al*., (1972) and Kahrs *et al*., (1978). The present sientific and medical literature contains a substantial number of works outlining current concerns, and again most of these appear to involve exotic pets. For example, Brugere-Picoux and Chomel (2009) state that most emerging disease in France is zoonotic with some causing unprecedented crises, and cite the exotic pet trade craze as a significant factor.

Relatedly, recent major scientific articles and reports published in the USA have emphasised that border controls do not meet the challenge of preventing incursion of zoonotic disease (as well as other threats, for example to agriculture and wildlife) from the exotic pet trade (Locke, 2004; Ehnert and Galland, 2009).

The Government Accountability Office for the United States surveyed major authorities and scientists involved in border protection and prevention and found that agencies need better collaboration to reduce the risk of animal-related diseases (GAO, 2009).

UK borders are also an imperfect membrane having, for example, performed poorly regarding avian influenza H5N1, which was significantly undetected in a consignment of imported pet birds (Anon., 2005). Fishes, amphibians and reptiles undergo no routine border quarantine. Comprehensive screening in general is either impractical or impossible and this represents a persistent biosecurity hazard for the UK. Tables 1a-d provides examples of fish, amphibian, reptile, bird, mammal, and mammal-primate-borne zoonotic infections and infestations.

Injuries (including bites and scratches), envenomations and stings from exotic pets and in other situations, including zoos, result in a small but important related animal-human health issue. National Health Service Health Episode Statistics for England conservatively indicate that between 2004 and 2010 there were 760 full consultation episodes at hospitals, 709 admissions, and 2,121 hospital bed days associated with injuries probably from exotic pets (Warwick and Steedman, submitted). Studies in France and Germany found 404 envenomation cases arising from mostly snake, fish and invertebrates between 1996 and 2006 (Schaper *et al*., 2009), although none were fatal. Many injuries, envenomations and stings may also result in infections.

Exotic pet-linked disease

By far the most significant zoonoses issue resides with the importation, trade and keeping of exotic pets. An exotic pet may be considered any animal that is non-native and non-domesticated. In England and Wales there are around 4,500 pet shops and an unknown but significant number of unlicensed commercial pet sellers (Warwick, Steedman and Lindley, 2011).

Pet Food Manufacturer's Association surveys (PFMA, 2009, 2010, 2011) including fishes, reptiles, and birds suggested that combined these animals occupy around 12.6% of UK homes and number approximately 42 million animals. Dogs and cats, by comparison, are present in around 40% of homes and may equate to approximately 16 million animals. The keeping of some exotic animals appears to be increasing dramatically. For example, between the 2009 and 2011, the number of UK homes with reptiles reached 1.6%, a rise in popularity of approximately 28% over three years (PFMA, 2009, 2010, 2011). With the possible exception of aquarium fishes, the great majority of exotics are probably maintained singularly or in very small numbers per household. An assortment of other exotic pets exists in relatively small numbers, including mammals such as civets, lions and kinkajous, and reptiles such as crocodiles.

In the USA in the 1960s and 70s pet turtles were found to be responsible for approximately 280,000 of all cases or 14% of human salmonellosis, and branded as significant and major public health hazards – a finding that resulted in a ban on small turtle sales, and a 77% reduction in the disease in the following year (Mermin *et al*., 2004). A slow re-emergence of other reptiles as pets has again resulted in raising prevalence of reptile-related salmonellosis (RRS) cases to around 70,000 or 3-5% of

	Disease	Genus of Pathogen	Source
Bacterial	Campylobacteriosis	*Campylobacter*	amphibian, reptile, bird, mammal-primate
	Endemic relapsing fever	*Borrelia*	amphibian, reptile, mammal
	Gastroenteritis	*Salmonella*	fish amphibian, reptile, bird, mammal, mammal-primate
		Staphylococcus	amphibian, reptile, bird, mammal
		Clostridium	amphibian, reptile, bird
		Escherichia	amphibian, reptile, bird, mammal
		Shigella	amphibian, reptile, mammal-primate
	Mycobacteriosis/Tuberculosis	*Mycobacterium*	fish, amphibian, reptile, bird, mammal-primate
	Salmonellosis	*Salmonella*	fish, amphibian, reptile, bird, mammal, mammal-primate
	Streptococcosis	*Streptococcus*	fish, amphibian, reptile
	Yersiniosis	*Yersinia*	amphibian, reptile, bird, mammal
	Septicaemia/general infection	*Acinetobacter*	amphibian, reptile, bird
		Alcaligenes	amphibian, reptile, bird
		Bacteroides	amphibian, reptile
		Clostridium	fish, amphibian, reptile, bird, mammal
		Citrobacter	fish, amphibian, reptile, bird, mammal
		Corynebacterium	amphibian, reptile, bird
		Enterobacter	amphibian, reptile, bird, mammal
		Enterococcus	amphibian, reptile, bird
		Fusobacterium	amphibian, reptile, mammal
		Klebsiella	amphibian, reptile, bird
		Moraxella	amphibian, reptile, bird, mammal
		Morganella	amphibian, reptile, mammal
		Pasteurella	amphibian, reptile, bird, mammal
		Edwardsiella	fish, amphibian, reptile, mammal
		Peptococcus	amphibian, reptile
		Proteus	amphibian, reptile, bird
		Pseudomonas	amphibian, reptile, bird, mammal
		Aeromonas	fish, amphibian, reptile, bird, mammal
		Serratia	amphibian, reptile, bird
		Staphylococcus	amphibian, reptile, bird, mammal
		Streptococcus	amphibian, reptile, bird, mammal
	Bartonellosis	*Bartonella*	mammal
	Pneumonia	*Klebsiella*	bird, mammal-primate
	Dermatitis	*Erysipelothrix*	fish, bird
	Psittacosis	*Chlamydophila*	bird, mammal
	Q-fever	*Coxiella*	reptile, bird, mammal
	Vibriosis	*Vibrio*	fish, amphibian, reptile, bird
	Brucellosis	*Brucella*	mammal
	Leptospirosis	*Leptospira*	amphibian, reptile, bird, mammal

Table 1.0a
Example exotic animal zoonotic infections and infestations – bacterial.
Derived from: Krauss (2003); Hubálek and Rudolf (2011); Weese and Fulford (2011); Frye (unpublished); Warwick (2006); Bridges et al., (2001); Chai et al., (2005), others.

Table 1.0b
Example exotic animal zoonotic infections and infestations – viral. Derived from: Krauss (2003); Hubálek and Rudolf (2011); Weese and Fulford (2011); Frye (unpublished); Warwick (2006); Bridges et al., (2001); Chai et al., (2005), others.

	Disease	Genus of Pathogen	Source
Viral	Hepatitis-A	*Picornavirus*	amphibian, mammal-primate
	Western encephalitis	*Togaviridus*	amphibian, reptile, bird
	West Nile virus	*Flaviviridus*	amphibian, reptile, mammal-primate
	Herpesvirus simiae-B	*Herpesvirus*	mammal-primate
	Monkeypox	*Poxviruses*	mammal-primate
	Molloscum contagiosum	*Poxviruses*	mammal-primate
	Measles	*Rubeola*	mammal-primate
	Rabies	*Rhabdoviris*	mammal, mammal-primate
	Haemorrhagic fever	*Marburg*	mammal-primate
	Avian influenza	*AIV H5N1*	bird
	Newcastle disease	*Paramyxovirus*	bird mammal
	Cowpox	*Orthopox*	mammal

Table 1.0c
Example exotic animal zoonotic infections and infestations – mycotic and allergen. Derived from: Krauss (2003); Hubálek and Rudolf (2011); Weese and Fulford (2011); Frye (unpublished); Warwick (2006); Bridges et al., (2001); Chai et al., (2005), others.

	Disease	Genus of Pathogen	Source
Mycotic	Coccidiomycosis	*Coccidioides*	amphibian, reptile, mammal
	Cryptococcosis	*Cryptococcus*	amphibian, reptile, bird
	Septicaemia	*Candida*	amphibian, reptile, bird
	Streptothricosis	*Dermatophilus*	mammal-primate
	Candidiasis	*Candida*	mammal-primate
	Ringworm	*Trichophyton*	mammal, mammal-primate
	Histoplasmosis	*Histoplasma*	bird, mammal
Allergen	Allergic alveolitis	*Avian antigen or mycotic spore?*	bird

all salmonelloses in the USA, and has again incurred warnings of health risks (Woodward *et al*., 1997; Mermin *et al*., 2004). Amphibian and reptile-keeping in the USA may involve approximately 9-11 million animals (APPA, 2005), whereas in the UK the figure is probably fewer than one million animals (PFMA, 2010).

Aitken *et al*., (2010) estimate that RRS may account for 1% or 1,160 cases in the UK annually. A study in Sweden (Hoelzer, Moreno-Switt and Wiedmann, 2011) that focused on data between 1990 and 2000 suggested that RRS there may have constituted around 5% of all cases of the disease and conclude that direct or indirect exposures to reptiles clearly represent a substantial risk to human health. The Hoelzer, Moreno-Switt and Wiedmann's (2011) findings closely resemble the USA experience and may suggest that the UK data are an underestimate. A case control study in 2009 indicated that reptile keepers in the UK were nearly 17 times more likely to get sick than those who had no contact with these animals (HPA, 2009a).

Attempts by the pet industry to eradicate Salmonella from reptiles were unsuccessful and led to the emergence

	Disease	Genus of Pathogen	Source
Micro-parasitic	Amoebiasis	*Entamoeba*	amphibian, reptile, mammal-primate
	Cryptosporidiosis	*Cryptosporidium*	fish, amphibian, reptile, bird
	Giardiosis	*Giardia*	mammal, mammal-primate
	Toxocariasis	*Toxocara*	mammal
	Schistosomiasis	*Schistosoma*	bird, mammal
	Scabies	*Sarcoptes*	mammal
Macro-parasitic	Sparganosis	*Diphyllobothrium*	fish, amphibian, reptile, bird, mammal
	Dracunculosis	*Dracunculus*	amphibian, reptile
	Fascioliasis	*Fasciola*	amphibian, reptile
	Larva migrans	*Gnathastoma*	fish, amphibian, reptile, mammal
	Loaiasis	*Loa*	amphibian, reptile
	Strongyloidiasis	*Strongyloides*	mammal, mammal-primate
	Hymenolepis	*Hymenolepsis*	mammal-primate
	Clonorchiasis	*Clonorchis*	fish
	Metorchiasis	*Metorchis*	fish, bird, mammal
	Heterophyidiasis	*Heterophyes*	fish, bird, mammal
	Echinostomiasis	*Echinostoma*	fish, bird, mammal
	Anisakiasis	*Anisaki*	fish
	Baylisascariasis	*Baylisascaris*	mammal
	Neuro-angiostrongyliasis	*Angiostrongylus*	mammal

Table 1.0d
Example exotic animal zoonotic infections and infestations – micro- and macro-parasitic. Derived from: Krauss (2003); Hubálek and Rudolf (2011); Weese and Fulford (2011); Frye (unpublished); Warwick (2006); Bridges et al., (2001); Chai et al., (2005), others.

of antibiotic resistant strains of the bacteria (Mermin *et al*., 2004). Methicillin-Resistant *Staphylococcus aureus* (MRSA) has also been isolated from many animals, including exotic pets (Weese, 2010).

Aleksandra *et al*., (2011) investigated 949 wild-caught and captive-bred reptiles imported into Slovenia from 2000 to 2005, and 68 different species for the presence of endo- and ectoparasites. In 26 (representing 47.3%) snakes, the authors identified 12 different groups including nematodes, trematodes, acanthocephalids, pentastomids and protozoans along with two different species of ectoparasites; in 252 (76.1%) lizards 18 different groups were identified including nematodes, cestodes, trematodes, acanthocephalids, pentastomids and protozoans. One trombiculid ectoparasite was also found. In 498 (88.5%) turtles, eight different groups including nematodes, nestodes, trematodes and protozoans were determined in animals. Three different species of ectoparasites were also observed in turtles.

Inoue *et al*., (2009) evaluated 546 small mammals of 28 species imported into Japan as exotic pets and identified isolates from 407 as *Bartonella* spp. of which four were zoonotic. Kasickova *et al*., (2009) studied 287 faecal specimens of captive exotic Psittaciformes, Passeriformes and Columbiformes birds purchased randomly from pet stores, avian breeders and keepers and screened for the parasite *Microsporidia* spp. and identified the organism in 40.1% of faecal samples.

The natural carriage of potentially pathogenic organisms and particles by exotic animals is possibly augmented by the introduction of supplementary microbes, for example bacteria, in the captive animal diet – which may then be propagated in the pet animal gut and later shed with magnified importance (Taormina, 2000; Hoelzer, *et al*., 2011).

Exotic pet keeping involves both overt and covert threats to public health. As with many risks, vulnerable

groups including children under five, the immunocompromised, and the elderly are at greater risk, but healthy young people are also affected. While the risk of some cases of potential infection can be reduced with conscientious attention to hygiene and other animal management protocols, in the domestic environment exotic pet keeping represents a continuous risk with no absolute resolving recommendation other than discouraging the practice.

The UK has issued formal warnings and guidance for over 10 years about health risks associated with reptile keeping (for example, Ward, 2000; HPA, 2009b. Despite repeated efforts at public education reptile-related salmonellosis cases continue to rise, and following a run of RRS cases in children in northern England in 2010, the HPA reiterated its 2009 guidance (HPA, 2009b).

Wildlife (pet) markets

The selling of exotic pets at pet fairs or wildlife markets is unlawful in the UK. However, some events remain, and for this reason, as well as the fact that UK citizens attend wildlife markets abroad, we briefly include them here. Pet markets have been highlighted as a significant risk to public health for several reasons. A large number and wide variety of species are held in close-confinement and this results in both stress for animals (which increases their own susceptibility to pathogens), as well as the opportunities for shedding, mixing and dissemination of potential pathogens. Furthermore, public direct and indirect contact with animals of uncertain origin and health state introduces a significant risk factor. Also, person-to-person contact is common and invites incidental microbial dissemination (Warwick, 2006).

A limited study of seven door handles at a major pet market in Germany in 2010 revealed two positive species of salmonella, S. *ramatgan* and S. *subspecies* V (PETA unpublished), both of which are reptile-associated. A detailed investigation of key European pet markets in 2011 (Arena, Steedman and Warwick, 2012) assessed visitor behaviour and public health implications and found that five-minute observation periods indicated that 3.6% of visitors had direct contact with animals and 27.3% had indirect contact, that is, contact with a presumed contaminated source, with subsequent modes of contact being 18.7% hand to mouth, 52.2% hand to body, and 19.9% person to person. Pet markets constitute an especially high risk of transmission of infectious agents to the public and these risks are fundamentally uncontrollable.

Zoo animal-linked disease

In the UK there exists 100 British and Irish Association Zoos and Aquariums (BIAZA) and possibly 245 non-BIAZA facilities (BIAZA, pers. comm.) holding an unknown number of animals. However, the Zoological Society of London, which is a large zoo, for example holds 18,499 animals (ZSL, 2011).

Publically accessible animal collections are described diversely as zoos, zoological gardens, safari parks, petting zoos, and farms. Some are distinctly identifiable as traditional zoos while others are less easily categorised. Given the sometimes loose structure of these facilities we will apply a relatively broad view. There appears to be little data on confirmed zoonoses from UK animal collections. However, numerous zoonotic incidents and outbreaks are associated with public visits to zoos.

Bender and Shulman (2004) reviewed and surveyed state public health veterinarians and epidemiologists in the USA and found that 11 published outbreaks of zoonoses had been identified as related to zoos, and farms, whereas an additional 16 unpublished outbreaks or incidents were identified unofficially. Also, most states had no formal guidance of zoonoses prevention and control. A tuberculosis outbreak affected seven handlers associated with rhinoceroses and monkeys in Louisana (Stetter *et al*., 1995). A salmonella-contaminated wooden handrail surrounding a Komodo dragon exhibit at a Colorado zoo in 1996 caused an outbreak of salmonellosis involving 65 confirmed cases and possibly several hundred unconfirmed cases (Friedman *et al*., 1998). Oh *et al*., (2002) found that 55 zoo employees showed evidence of *Mycobacterium* (tuberculosis) presence, although none had the active disease.

In a study of primates, carnivores, perissodactyls, artiodactyls and proboscideans at two Italian zoos, Fagiolini *et al*., (2010) found one or more intestinal parasites were present in 61.5% of samples, including *Cryptosporidium* spp., *Toxocara* spp., and *Strongyloides* spp., and concluded that zoonotic protozoans and gastrointestinal helminths are common in zoo mammals. Beck *et al*., (2011) studied 131 faecal samples of 57 mammalian species at Zagreb Zoo for the presence of *Giardia* spp. and found prevalence to be 29%, while all animals were asymptomatic. In another study of *Giardia* spp. among zoo primates in Spain, Martinez-Diaz *et al*., (2011) obtained 20 faecal samples from 16 species of which 70% were positive. Levecke *et al*., (2007) analysed 910 faecal samples from 222 primates of 31 species in four zoos and found the protozoans *Entamoeba* spp. and

Giardia spp. prevalence to be 44% and 41% respectively. Ledwon *et al*. (2008) examined 425 zoo parrot faecal samples for the presence of *Mycobacterium* spp. and found 73 samples to be positive, although the subtypes were mostly of moderate human pathogenicity. A Danish study identified 43 typically exotic salmonella serovars, mostly from zoo reptiles (Pedersen *et al*., 2009).

A study of 60 workers at an Austrian zoo screened for the prevalence of antibodies against selected zoonotic agents found markers indicating that 97% of individuals had been exposed to at least one zoonotic agent, although in some cases exposure may have been owing to situations outside the zoo environment (Juncker-Voss *et al*., 2004).

Petting zoos

Petting zoos are either autonomous animal collections or sections of larger facilities where the public, often children, are granted direct access to animals. While some are formally defined, others are arbitrary arrangements within events such as animal shows. Domesticated and farm animals are commonly present, but often exotic species including tortoises, lizards, snakes and llamas are also available.

Keen *et al*., (2007) report that in the USA since 1999 there have been at least 17 agricultural fair, petting zoo, or open farm related *Escherichia coli (E. coli)* outbreaks, affecting 1,317 people and resulting in 69 hemolytic-uremic syndrome cases and two deaths.

The variety of 'petting' species involved implies potentially diverse microbial and macroparasite threats, for example, Salmonellosis and other gastroenteric disorders (*Salmonella spp., E. coli*), *Cryptosporidium* spp. Q-fever (*Coxiella* spp.), tuberculosis (*Mycobacterium* spp.), ringworm (*Trichophyton* spp.), and threadworms (*Strongyloides* spp.), and the direct contact nature of these events is a notable concern (Chomel *et al*., 2007). A study by Keen *et al*., (2007) of *Salmonella enterica* and Shiga-toxigenic *E. coli* O157 among 997 subclinical animals at 36 contact exhibits in Association of Zoos and Aquariums-accredited facilities in the USA found that prevalence was less than 0.6%, although these findings relate to a small number of potentially pathogenic bacterial agents.

Circus animal-linked disease

The UK is thought to have eight circuses holding fewer than 40 exotic animals (Captive Animals Protection Society, pers. comm., 2011). Exotic animals present in circuses include elephants, llamas, camels and other large mammals as well as some large reptiles, for example pythons and crocodiles, and public access to circus animals is sometimes permitted under supervision. Nevertheless, a range of reptile- and mammal-borne infections and infestations are associated with circus animals, perhaps most notably tuberculosis (Michelak *et al*., 1998) and cowpox (Hemmer *et al*., 2010; Hubálek and Rudolf, 2011).

With regards to circuses, handlers are probably most at risk, and in one outbreak, twelve animal handlers in Illinois contracted tuberculosis from infected elephants (Michelak *et al*., 1998). Contact with reptiles including pythons and crocodiles involves the potential risk of many bacterial infections, most notably salmonellosis (Mermin *et al*., 2004).

Prevention and control of disease

Healthcare providers are generally poorly informed regarding the potential threats from zoonoses (Rosen and Jablon, 2003), which is particularly disturbing given the relative prevalence of, in particular, exotic pet keeping. Under-ascertainment and misdiagnoses of zoonoses are probably frequent in part because healthcare professionals fail to ask pertinent questions regarding household habits and fail to distinguish zoonotic disease from superficially similar common conditions (Warwick, 2004). For example, it is highly likely that the true number of reptile-related salmonellosis is underestimated through cases being incorrectly attributed to contaminated or inadequately cooked food products, a more commonly recognised route of transmission.

While some zoos are encouraged to formulate both public and occupational health plans to prevent zoonoses (Roberts, 1995) and several protocols are in place around the world, for example, Miller (2011), HSE (2011), the exotic pet and circus industries appear less well prepared. The UK has general guidelines for investigating of zoonotic disease (HPA, 2009c).

There are at least two examples of husbandry-related legislation that, when properly enforced, may help to prevent the spread of zoonoses – the Dangerous Wild Animals Act 1976 (DWAA) and the Zoo Licensing Act 1981 (ZLA). The DWAA was introduced to ensure that potentially dangerous animals pose no risk to the public, although pet shops themselves are exempt from the regime. The ZLA is a quality assessment requirement for zoological collections in Great Britain. Both these Acts are regulated via local authority licensing. While there may be

clear potential for both the DWAA and the ZLA to reduce zoonotic risks, the lack of historical and current epidemiological data precludes assessment regarding the possible contributions offered by these legal frameworks.

Contamination, hygiene and hand washing

For several years formal advice has been issued in order to reduce public exposure to zoonotic disease, in particular, reptile-related salmonellosis. Some of this advice has attempted to balance reptile-keeping with hygiene measures, for example an information leaflet jointly produced by the Department of Health, Department of Environment Food and Rural Affairs and the Health Protection Agency (HPA, 2009b).

A key feature of current advice involves recommending hand washing as a protection against infection and transmission. Another example is that advice issued by some local authorities to organisers of some animal shows has included the use of disinfectant sprays and gels as part of disease prevention and control. However, in relation to farm visits, for example, the Health Protection Agency (UK) importantly points out that disinfectant sprays and gels are not wholly reliable materials for cleansing hands and safeguarding against infection, and recommend additional thorough hand washing with soap and water as improved protection (HPA, 2011).

Hand washing has been shown to have positive health benefits and save lives from infectious disease. Two factors are theoretically involved in hand washing – direct removal of unwanted material and the neutralisation of active microbial agents.

There are numerous studies monitoring and comparing the efficacy of different hand washing methods (for example, rubbing hands and non-rubbing hands) and chemical sanitisers (for example, alcohol, plain soap, and antibacterial soap) (Doebbeling *et al*., 1988; Girous *et al*., 2002; Fischler *et al*., 2007; Grayson *et al*., 2009; Jabbar *et al*., 2010) and this research shows varying degrees of reduction in bacterial density on relevantly treated hands.

However, a key yet often-overlooked result is that although hand washing typically achieves varying *reductions* in microbial density it does *not eliminate* potential pathogens. This equates to a reduction but *not* elimination in risk or protection from disease.

Hand washing as a recommendation is also well known to be poorly adhered to and performed, and compliance among even professional healthcare workers rarely exceeds 40% (Trampuz and Widmer, 2004). This does not inspire confidence in animal-related personnel or the public adopting stringent hand washing even where advised to do so.

Surgical gloves offer another well-recommended mechanism for reducing contamination, although again this does not offer complete protection as microbes have been shown to penetrate this barrier and contaminate underlying skin (Doebbeling *et al*., 1988). Indeed, glove microbial leakage is known to attain 4% to 63% for vinyl and 3% to 52% for latex (Larson, 1995) – making further disinfection of hands essential even where gloves have been used.

Simply, hand washing as generally practised does not provide reliable protection against animal-borne contaminants. While an understandable recommendation, hand washing – with and without disinfectant gels and sprays – may generate undue over-reliance and misplaced confidence regarding disease prevention and control, and this may lead to infection from complacency (Warwick, Lindley and Steedman, 2011).

In order to safely cleanse human hands rigorous cleansing with powerful antimicrobials comparable to pre-theatre surgery protocols are required. Such measures are practically impossible in the domestic environment. Also, theoretically cleaned hands likely remain at least residually contaminated and easily capable of spreading microbes over diverse surfaces including an individual's clothes, hair, and skin, as well as inanimate objects and other people around them (Warwick, *et al*., 2001). Further, surgically-cleansed hands remain liable to rapid re-contamination via momentary contact with any previously contaminated source (Warwick *et al*., 2001).

No level of hand hygiene offers protection to human skin against scratches and bites from animals. Relatedly, direct contact between any animal and open human lesions, such as sores, or via debris reaching the human mouth, eye or ear are additional potential routes of infection (Warwick *et al*., 2001). Aquatic animals may quickly contaminate large volumes of water – resulting in risks from splashes, droplets, and smears.

In brief, hand washing, with gels, sprays and domestic soaps is not a reliable method of preventing animal-borne human infection and great caution is required on how such advice is presented in future.

Zoonosis/condition	Source	Signs & symptoms
Salmonellosis/gastroenteritis	Fish, amphibian, reptile, bird, mammal	Nausea, vomiting, diarrhoea, abdominal cramps and pain, fever, painful joints, meningitis, flu-like
E. coli infection/gastroenteritis	Amphibian, reptile, bird, mammal	Nausea, vomiting, diarrhoea, abdominal cramps and pain, fever, painful joints, meningitis, flu-like
Campylobacteriosis/astroenteritis	Amphibian, reptile, bird, mammal-primate	Nausea, vomiting, diarrhoea, abdominal cramps and pain, fever, painful joints, meningitis, flu-like
Leptospirosis	Amphibian, reptile, bird, mammal	Flu-like, vomiting, icterus, telangiectasia, uveitis, splenomegaly, meningitis
Psittacosis	Bird, mammal-primate	Flu-like, pneumonia, fever, cough
Vibriosis	Fish, amphibian, reptile, bird	Gastrointestinal, pain, vomiting, fever, otitis
Lyme disease/bartonellosis	Mammal	Flu-like, fever, rash, gastrointestinal
Toxocariasis	Mammal	Eye problems
Giardiasis	Mammal-primate	Gastrointestinal, fever, nausea, fatigue, weight loss
Tuberculosis	Fish, amphibian, reptile, bird, mammal-primate	Respiratory, flu-like, fever, weight loss
Q-fever	Reptile, bird, mammal	Fever, flu-like
Cryptosporidiosis	Fish, amphibian, reptile, bird	Acute gastrointestinal disturbance, nausea, vomiting, pain, fever, flu-like
Macroparasite infestation	Fish, amphibian, reptile, bird, mammal, mammal-primate	Gastrointestinal disturbance, abdominal cramps and pain, weight loss, flu-like
Ringworm	Mammal, mammal-primate	Patchy skin, inflammation, itching
Allergic alveolitis	Bird	Persistent dry cough, chest irritation

Table 2.0
Common zoonoses signs and symptoms. If experiencing these indicators report to a healthcare professional. These are a small sample of relatively common animal-to-human diseases.

Important: The onset of signs and symptoms of an animal-related disease may occur within hours or not for several weeks or months following exposure to an exotic animal. Most cases of diseases are not serious, but it is important to report any suspicion of having an animal-linked disease because treatment may vary from regular illnesses and early access to medical help can alleviate greater problems as well as assist health workers provide best advice.

Conclusions and recommendations

Of the three primary subjects considered in this report, exotic pets, zoos, and circuses, we have no reservations in stating that the overwhelming evidence shows that by far the greatest potential threat to human health resides with the trade in and keeping of exotic animal pets. Not only are exotic pets well established as sources of diverse pathogens, direct and indirect contact associated contamination, and significant and major sources of human disease, but their increasingly ubiquitous occupation in the home presents close-quarter and enduring risk factors. Further, poor understanding of risk factors throughout the trade and keeping chain, which sometimes continues into the healthcare and public health professions, sets exotic pet keeping apart as an important threat to public health.

Table 3.0
Possible useful standard-setting questions to ascertain source of infection. (Reproduced from Warwick 2004).

a	recently consumed foods (and their condition)
b	visits to restaurants
c	foreign travel
d	visits to hospital
e	visits to farms
f	visits to zoos and other wildlife centres
g	visits to a pet shop
h	whether the patient household possesses any pets
i	whether the patient has visited a household that possesses pets
j	whether in particular in c-g above, the patient or others in the household may have had direct or indirect contact with persons or inanimate material from these categories

Both zoo animal populations and public attendance at zoos are substantial, and zoonotic episodes and outbreaks are known from direct and indirect contact with animals. Wherever possible direct human contact with zoo animals should be avoided. Where no direct public-animal contact is involved a potential risk remains from possibly contaminated intermediary areas and surfaces to which the public have access. However, although many people visit zoos, attendance is occasional and thus involves relatively low exposure to zoonotic risk. Exposure to zoonotic threats as encountered in zoos should, however, be treated as significant, and continuous awareness of zoonoses should be maintained for zoo personnel as well as greater education regarding public attendees.

Public attendance at circuses too can be considerable, and zoonotic episodes and outbreaks are known from direct and indirect contact with circus animals. While the number of animals in circuses may be relatively low, microbial dissemination to wider areas, including discrete locations (as for pet and zoo scenarios), should be presumed, causing all publically accessible areas to be potentially contaminated.

The fact that data on cases and prevalence are sparse should not be presumed to indicate that actual prevalence is low. Our view is that zoonoses are stealthy infiltrative infections and infestations that are probably pervasive and masked by under-reporting and misdiagnosis.

Education

We recommend that all pet shops, zoo-animal sections, and circuses maintain a 'zoonoses signs and symptoms' chart to increase awareness and offer early alert to personnel for possible infections and infestations (see Tables 1a-d and 2). Local authorities may wish to improve their own awareness of zoonoses monitoring (see Table 3). A simplified point of contact or sale 'take-away' awareness and guidance notice should be provided to all public attendees on entry to any pet shop, zoo or circus (see Figures 1 and 2).

Future guidance may include advising against keeping exotic animals as pets unless excellent monitoring for diseases and essential husbandry practices are pursued, as well as offer clear and uninhibited instruction on disease prevention and control so that people attending animal centres or purchasing animals are well informed of potential risks.

Record-keeping

While zoos often maintain good inventories of all animals, their histories, morbidities, treatment and mortalities, the same cannot be said of pet shops. This lack of self-monitoring is concerning because not only can this facilitate the unchecked spreading of disease, but also zoonotic outbreaks may not be preventatively intercepted. Accordingly, we recommend that all pet shops, zoos and circuses maintain comprehensive inventories including: all animals 'in and out'; full morbidity and treatment records; post-mortem reports for deceased individuals where recommended by a veterinary surgeon; and a list of all suppliers of animals to as well as all purchasers (or other acquirers) of animals from any animal centre. This, more comprehensive and responsible approach to dealing with prevention of

EXOTIC PETS

HYGIENE AND CAUTIONS

IMPORTANT: Hygiene measures, such as hand-washing, where performed thoroughly and with correct chemicals, can significantly reduce the amount of germs on your hands but *does not* guarantee protection against becoming sick or remove the possibility of passing germs directly or indirectly to others.

Advice included here can help to *reduce* but not *eliminate* the risk of contracting illness from exotic pets.

Ownership of exotic as pets such as fishes, amphibians, reptiles, birds, and mammals such as raccoons and primates involve special risks to the health of animal keepers and to the health of those around them. *It is not advisable to keep exotic animals as pets*. Many people, however, already have exotic pets, and this most likely causes thousands of cases of human illness annually and occasional deaths.

It is important to note that because exotic pets occupy the home, and that germs are easily spread around surfaces, walls, door-handles, clothes and other items, even thoroughly cleaned hands can quickly become contaminated again by simple contact with any of these items. Pet stores and the people who work there should also be regarded sources of contamination. Thorough cleaning of exotic pet-related germs from the home may be practically impossible.

- *Children should be supervised so that they do not put their mouths close to or kiss exotic animals.*
- *Do not eat, drink or smoke whilst handling an exotic animal.*
- *Always wash your hands thoroughly after touching or handling any exotic animal, their cage or any other equipment.*
- *Dispose of waste water and droppings from exotic pets down the toilet – and not in the sink or bathtub.*
- *Always wash your hands immediately and thoroughly after feeding your exotic pet and after handling raw (including frozen or defrosted) mice, rats and chicks.*
- *Ensure that all surfaces that come into contact with exotic pet animals, (including areas that you may have touched), and raw or defrosting exotic animal food are cleaned thoroughly afterwards.*
- *Do not use kitchen sinks to bathe exotic pets or to wash their cage or equipment. If you use a bathroom sink or bathtub, it must be cleaned thoroughly with disinfectant afterwards.*
- *It is strongly advised that anyone handling an exotic animal or an object that may have been in contact with an exotic animal should wash their hands immediately and thoroughly afterwards. First use antibacterial soap and water, taking care to rub hands vigorously together, being careful to clean all areas. Second, apply an alcohol-based cleaning agent.*
- *If you touch any exotic animal, avoid further touching your hair, clothes (including pockets), doors and other items (including car doors, steering wheels and gear change levers) until you have thoroughly cleansed your hands.*
- *Thoroughly cleaning hands is particularly important before touching or feeding a baby or young child. Not to do so would pose a strong health risk to the infant.*
- *Local authorities, doctors, vets facility managers should advise their patients and customers of the health risks associated with having an exotic animal as a family pet and should provide appropriate health protection advice.*

Figure 1.0
Avoiding animal-linked disease associated with exotic pets

Figure 2.0
Avoiding animal-linked disease associated with zoos, petting zoos, open farms, and circuses

ZOO ANIMALS, PETTING ZOO ANIMALS, OPEN FARM ANIMALS, AND CIRCUS ANIMALS

HYGIENE AND CAUTIONS

IMPORTANT: Hygiene measures, such as hand-washing, where performed thoroughly and with correct chemicals, can significantly reduce the amount of germs on your hands but *does not* guarantee protection against becoming sick or remove the possibility of passing germs directly or indirectly to others.

Advice included here can help to *reduce* but not *eliminate* the risk of contracting illness from zoo animals, petting zoo animals, open farm animals, and circus animals.

Some zoos, petting zoos, open farms, and circuses allow public contact with animals. It is important to note that the animals, their handlers and the general environment around them including fences, stand-off barriers, seats, and other common and even remote areas can harbour germs, and even thoroughly cleaned hands can quickly become contaminated again by simple contact with any of these items.

Because visits to these centres are infrequent and exposure to animals often minimal, risks of contracting animal-linked diseases are relatively low, but must not be overlooked.

- *Children should be supervised so that they do not put their mouths close to or kiss exotic animals.*
- *Do not eat, drink or smoke whilst handling an animal.*
- *It is strongly advised that anyone handling an exotic animal or an object that may have been in contact with an exotic animal should wash their hands immediately and thoroughly afterwards. First use antibacterial soap and water, taking care to rub hands vigorously together. Second, apply an alcohol-based cleaning agent.*
- *If you touch any exotic animal, avoid further touching your hair, clothes (including pockets), doors and other items (including car doors and steering wheels and gear change levers) until you have thoroughly cleansed your hands.*
- *Thoroughly cleaning hands is particularly important before touching or feeding a baby or young child. Not to do so would pose a strong health risk to the infant.*
- *Local authorities, doctors, vets facility managers should advise their patients and customers of the health risks associated with visiting zoos, petting zoos and open farms and should provide appropriate health protection advice.*

disease will greatly assist in contact-tracing members of the public in the event of a zoonotic outbreak being linked to that facility.

Inspection and monitoring

Local authority (LA) health inspectors have an important role in the recognition of potential disease outbreaks and their sources. Table 3, originally published as advice to General Practitioners, is equally valid for LA inspectors reporting on suspect conditions.

Local authorities may wish to liaise with pet shops, zoos and circuses, and perhaps also animal rescue centres, and enquire whether they hold existing protocols for the control of zoonoses, and where in-situ ascertain whether upgrades are needed. Zoonoses prevention and control protocols should be obligatory. Again, some of the material in this report may assist with template-formation for upgrading (or instituting) protocols.

Local authorities should periodically observe animal facility hygiene protocols and their advice to the public as well as

conduct periodic microbiological analyses of facilities for the prevalence of potentially pathogenic agents.

Hygiene protocols

We consider that formal advice on contact with exotic animals requires urgent upgrading. LAs should emphasise that while thorough hand-washing with antimicrobial chemicals may help to reduce the risk of infection, the process itself neither guarantees clean hands nor protects against rapid recontamination from proximal items and surfaces and thus does not offer reliable protection against animal-borne disease. Hand washing may be of minimal or negligible efficacy where continuous exposure to contamination sources is involved, for example with exotic pets in the domestic environment. While there is strong evidence implicating exotic pet keeping as a major public health hazard, further research is needed into possible prevalence of zoo-, petting zoo- and circus animal-acquired zoonoses.

Develop a zoonotic disease response plan

As per Locke's (2004) recommendations, which we have adapted for the UK, environmental health services in consultation with the Department of Health and centres for disease control and prevention, should work with interested parties including private organisations, research institutions, health care providers, and veterinarians to develop a zoonotic disease response plan. A response plan should be a dynamic resource that can be readily changed as circumstances require.

Threats to public health from zoonotic risks increase in relation to the level of exposure to potential pathogens and transmission opportunities. Greater numbers of animals and diversity of species incur significantly increased risk of human infection and infestation diseases. Accordingly, local authorities may wish to consider modifying facility operators' license conditions to include greatly restricting the numbers of animals and types of species that can be held or sold.

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