Review

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Zoonotic pathogens in urban animals: Enough research to protect the health of the urban population?

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Abstract

With more than half of the global population living in cities, the urban areas are also teeming with animals, including peridomestic wildlife, pets, and livestock. Urban animals may carry zoonotic pathogens, and crowded conditions in cities can increase the risk for the human population. We used a systematic approach to screen two publication databases as well as gray literature, and quantified the studies conducted on zoonoses in urban animals with respect to the geographic distribution, the host animal and pathogens. Out of 876 references found, 93 were included into final data extraction. Few studies were from the rapidly expanding cities in low- and middle-income countries where urban livestock-keeping is far more prominent than in high-income countries. Most studies were performed in peridomestic wildlife and pets, less in livestock. The most common category of pathogens studied were gastrointestinal parasites followed by gastrointestinal bacteria, whereas studies on some other zoonoses internationally recognized as critical for public health were few or absent. In conclusion, to mitigate the risks of emergence of zoonoses from urban animals this review highlights the research gaps on zoonoses, particularly in livestock in rapidly growing tropical cities and a more comprehensive inclusion of pathogens prioritized by WHO and OIE.

Introduction

In today's world of more than 7 billion people, more than 50% of them already live in urban areas, and this proportion keeps increasing (Satterthwaite *et al.*, 2010; Bloom, 2011). The urban population needs food, and with an increasing middle-income class, the demand for animal-source foods is increasing (Rae, 1998). The provisioning of fresh food is challenging, especially in low- and middle-income countries where infrastructure is poor and it may be impossible to maintain cold chains, forcing slaughter to occur closer to the urban consumers. This creates an increased market for urban produced animal-source foods and an economic incentive for urban livestock keeping (Schiere and van der Hoek, 2001; van Veenhuizen and Danso, 2007). Also, due to high land prices and the general shortage of space in cities, production of perishable products, including animal products, with high market values and less demand of land are often preferred (De Zeeuw and Lock, 2000; Nugent, 2000; Midmore and Jansen, 2003). Animals can give a high turnover on a limited area, and the scavenging behavior of many animals, such as pigs and chickens, make them possible to keep even without land (Schiere and van der Hoek, 2001; van Veenhuizen and Danso, 2007).

Even though urban livestock keeping is providing food and livelihood to urban farmers and consumers, as well as different value chain actors, there are downsides to it, such as the public health risks. Livestock keeping in dense urban areas cause sanitary problems with the disposal of manure, attracts disease vectors and scavengers and may serve as reservoirs for pathogens and can therefore constitute an increased risk for emergence and transmission of zoonoses (De Zeeuw and Lock, 2000; Schiere and van der Hoek, 2001).

In addition to the urban livestock, cities contain a high density of pets, including feral domestic pets such as stray dogs and cats, as well as wildlife, for which cities may particularly provide ample opportunities for peridomestic scavengers. Urban areas create specific ecosystems with higher temperatures, 'urban heat islands', and less seasonal changes, which coupled with the establishment of anthropophilic mosquitoes in urban centers, particularly in tropical regions, may contribute to the emergence of vector-borne diseases (Gubler, 1996; Shochat *et al.*, 2006; Bradley and Altizer, 2007; Saxena *et al.*, 2011; Lindahl *et al.*, 2013). The movements of humans and animals in and out of high-density cities, mean that zoonotic spill-over events, that previously could have caused isolated outbreaks in remote rural areas, now have increased risks of being spread within urban areas, and thereby increasing the potential for continued human-to-human transmission (Morse, 1995; Cutler *et al.*, 2010). In fact, most of the emerging infectious diseases in humans are zoonotic (Taylor *et al.*, 2000; Jones *et al.*,

2008), making the cities crowded with both animals and people likely hotspots for future disease emergence.

Urban livestock keeping is of increasing importance for providing highly nutritious animal-source foods, livelihoods and public health. However, most research on the risks associated with livestock and zoonotic pathogen transmission are still conducted with a rural focus. This review was conducted to screen the available literature on zoonoses in urban animals, in order to identify knowledge gaps in this field, critical for public health interventions, particularly with respect to geographical distribution of the studies and pathogens studied.

Material and methods

This review used a systematic approach to obtain thorough and unbiased results that are transparent and replicable (Protocol in supplementary material 1), but did not follow all the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) and the protocol was not peer-reviewed. In addition, because the scope was so wide, no attempt was made to conduct a meta-analysis, and because the aim of the review did not contain any research questions regarding an intervention, it was not applicable to have all PICOS (participants, intervention, control, outcome, study design). The retrieval of literature for this study was conducted in four steps.

First, for the literature search in scholarly databases, keywords were chosen and search strings were defined (Supplementary material 1). More specifically, 28 keywords were selected to create 26 search strings, which were then used to search the three databases PubMed, CAB Direct and Web of Science. The inclusion criteria were that the abstract was in the English language, literature was published from 2003 to 2013 (until November 2013), research was performed in urban areas, it was original research on animals and at least one zoonotic pathogen was studied. Second, citations were downloaded into the reference manager, Mendeley (Mendeley Ltd), and duplicates were removed. The total publications retrieved from all three searches were 876 and after the duplicates were deleted, the final number of references was 398. In addition, 11 'gray literature' papers were found by searching institutional databases (Table 1); all of these were however excluded after screening because they did not fulfill the inclusion criteria.

Third, abstracts were reviewed by the two authors independently. When there was disagreement between reviewers, the abstracts were re-reviewed by one of the reviewers and accepted if at least one reviewer was considering that the paper should be included; in total 140 abstracts were included at this stage. For these abstracts, the full papers were sought and downloaded if available.

Fourth, abstracts and full papers, when available, were then reviewed, and data were extracted from all papers and abstracts fulfilling the inclusion criteria listed above. This study used the criteria for poor quality as reported by Alonso et al. (2016), in short, poor quality was defined as methods not clear or incomplete, inappropriate methods or data analyses, biased or potentially biased selection that is not acknowledged, and reported results that are incomplete, unclear, or inaccurate.

Classifications of extracted data

A template was created in MS Excel to extract relevant data (Supplementary material 2). A journal was classified as being an ISI journal if it is listed in Thomson Reuters Web of Science (http://ip-science.thomsonreuters.com/mjl/). A study was considered to study multiple pathogens if the pathogens belonged to different genera. A study including multiple species of Brucella or Echinococcus, respectively, would therefore not be considered a multispecies study. Type of study (a prevalence study, a study to evaluate risk factors, or other studies) was classified depending on what seemed the main purpose of the paper. In many cases however, a paper reported both prevalence data and risk factors analyzed.

The studies were classified as being urban, rural, or peri-urban, based on what was stated in the paper, or how the area was described. One problem with studies on urban agriculture has been the lack of common definitions of what constitutes urban or peri-urban (Mougeot, 2000; Satterthwaite et al., 2010). For this purpose, each paper was judged on if it provided some kind of definition used in the paper, or a description of the study areas that would help comparisons with other studies.

Probabilistic sampling was concluded when the paper reported random sampling, and was considered explained if there was any methodology at all describing the method. For the purpose of this paper, the use of road kills or traps without a specified randomization protocol is considered as convenience sampling (Anderson, 2001).

Results

Papers included

After screening of the abstracts, 140 papers were included. At this stage, it was attempted to retrieve the full documents of these, and data were extracted. An additional 47 papers were excluded when full papers were reviewed. The most common reasons for exclusion were that it could not be verified that the study was conducted in urban or peri-urban areas (7), the paper did not actually study a zoonosis (12), the paper did not include a study in animals, but only in human beings (14), soil (5) or food products (1), or other reasons (8). Five papers studying knowledge, attitudes and practice about zoonoses were retained, even though they did not include animal studies per se. One additional paper also studied knowledge, attitudes and practices in addition to looking at prevalence in animals. The final number of included papers from which data were extracted were 80 full papers and 13 abstracts (Fig. 1). For some of the abstracts evaluated, there were full papers available online but in other languages, most commonly Spanish and Portuguese. Five papers were not published in ISI journals; three of these were published as conference proceedings.

The included papers were published between 2004 and 2013, and in 64 (69%) papers it was possible to find out when the study had been conducted or ended, in cases of longitudinal studies. According to the papers that provided this information, studies were conducted between 2001 and 2012, and there was an average of 2.8 (range 1–10) years between the stated year of ending a study and the year of publication.

Sixty of the 80 full papers were considered of acceptable quality, whereas 20 papers were judged to be of poor quality because there were no data on sample selection or collection, an unclear randomization process, inaccuracies in data, difficulties in understanding methodology, results or how results were obtained and unsubstantiated conclusions. Two of the papers judged to be of poor quality were published as proceedings for conferences.

Table 1. Institutional databases screened for studies on zoonoses in urban animals during 2003–2013, and the number of studies found using search terms (hits) and how many were imported to be screened

Database	Hits	Included
Food and Agricultural Organization (FAO)	7	2
World Health Organization (WHO)	5	2
International Livestock Research Institute (ILRI)	14	4
World Bank (WB)	3	0
Organisation for Economic Co-operation and Development (OECD)	7	1
World Animal Health Organization (OIE)	2	2
European Centre for Disease Control (ECDC)	0	0

Fig. 1. Flowchart of the review process.

Geographical distribution and types of urban animals

Research had been conducted in all permanently inhabited continents (Fig. 2), with 32% of the papers on studies conducted in South America, 18% in Europe, 16% in North America, 14% in Africa and 6% in South and Southeast Asia, each. Because research purely on human populations were excluded, the remaining papers could be classified as (1) research on domestic animals, 53 papers, including research on livestock and pets, feral and stray domestic animals, (2) research on wild animals, 40 papers, and (3) 5 papers focusing only on knowledge, attitudes and practices (Fig. 3). There was a trend of increasing numbers of papers with time (Fig. 4).

Research was conducted either in urban, peri-urban or both urban and rural. In addition, one study was defined as suburban, and two were described as semi-urban; for the purpose of the summary, these were judged to be peri-urban studies. In five papers, a description of the study site could not be found that enabled classifying into either category. In 68 papers (72%) there was no definition of urban and peri-urban, or any description of the sampling locations that could facilitate comparisons with other studies (Fig. 5).

A purposive sampling methodology was stated in five papers, six papers stated a probabilistic sampling without explaining how, and 12 papers described the way a probabilistic sampling had been conducted. The most common way (28 out of 39 studies) of investigating wild animals was through opportunistic traps or road kills. For the majority of papers, sampling was either not probabilistic, or it could not be concluded from the paper.

Urban zoonotic pathogens

Most studies focused on only one pathogen. However, 27 studies included multiple pathogens, especially studies on gastrointestinal helminths (14 papers). In total, 55 studies included parasites, 30 bacterial diseases, 18 viral, and one fungal. The most frequently studied pathogens are listed in Table 2.

Viruses

Avian influenza virus. Half of the papers on avian influenza or influenza A focused on screening for the virus, and the other half were on knowledge, attitudes and practices. Both surveys screening for influenza were from Germany and did not find the virus in neither 364 pigeons (Kohls et al., 2011) nor 486 b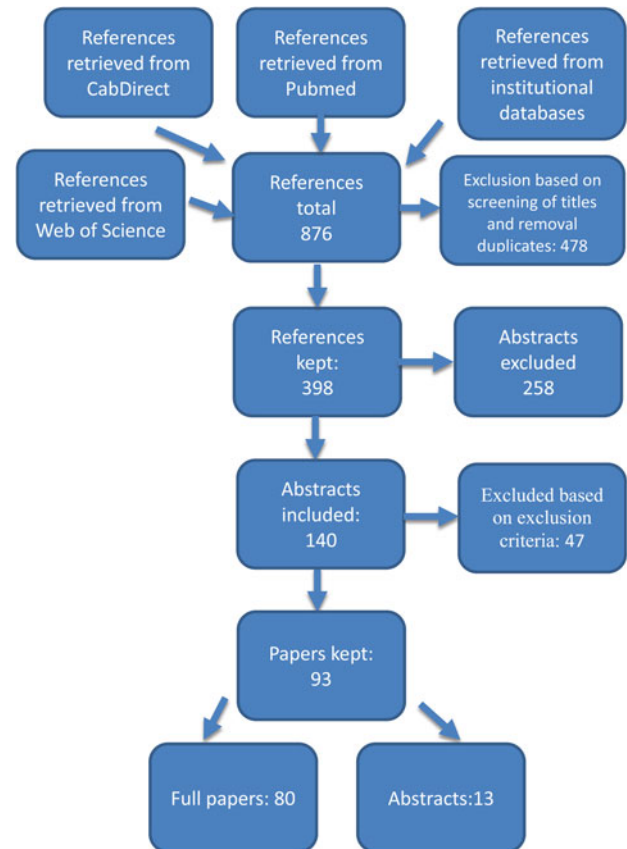ats (Mühldorfer et al., 2011). The other two papers reported on knowledge, attitudes, and practices among households in Turkey and Laos (Barennes et al., 2010; Bakiray Küçükkaya et al., 2011), with both studies emphasizing that more awareness was warranted in both urban and rural areas.

Rabies virus. All six studies on rabies were conducted in the Americas, half on wildlife (two on bats) and half on dogs. In Texas, US, trends of increasing rabies-positive skunks and bats were seen in urban areas (Oertli et al., 2009; Mayes et al., 2013). Studies in Maracaibo, Venezuela, found more than 1000 cases of canine rabies in the city, and an association with dogs having access to the streets and the social status of the family (Prieto et al., 2006; Fuentes et al., 2008). Paez et al. (2009) studied control of urban rabies outbreaks in Santa Maria, Colombia, and found it was important with urgent vaccination programs during outbreaks, but in spite of this less than 50% of dogs had protective titers after vaccination.

Other viruses. The other publications about viruses included reoviruses, picobirnaviruses, arenaviruses, hantaviruses, and the vector-borne West Nile virus.

Bacteria

***Brucella* spp.** Studies on *Brucella* spp. were all focused on seroprevalence in ruminants (mainly cattle) in Asia and Africa, although in one proceeding the methodology was unclear and it was unknown how many animals originated from urban areas. Apart from one study in Tajikistan (Jackson et al., 2007) which included small ruminants, the other four studies were conducted in Africa on cattle only. The highest prevalence reported at household level, both rural and urban, was in Tajikistan with up to 17%
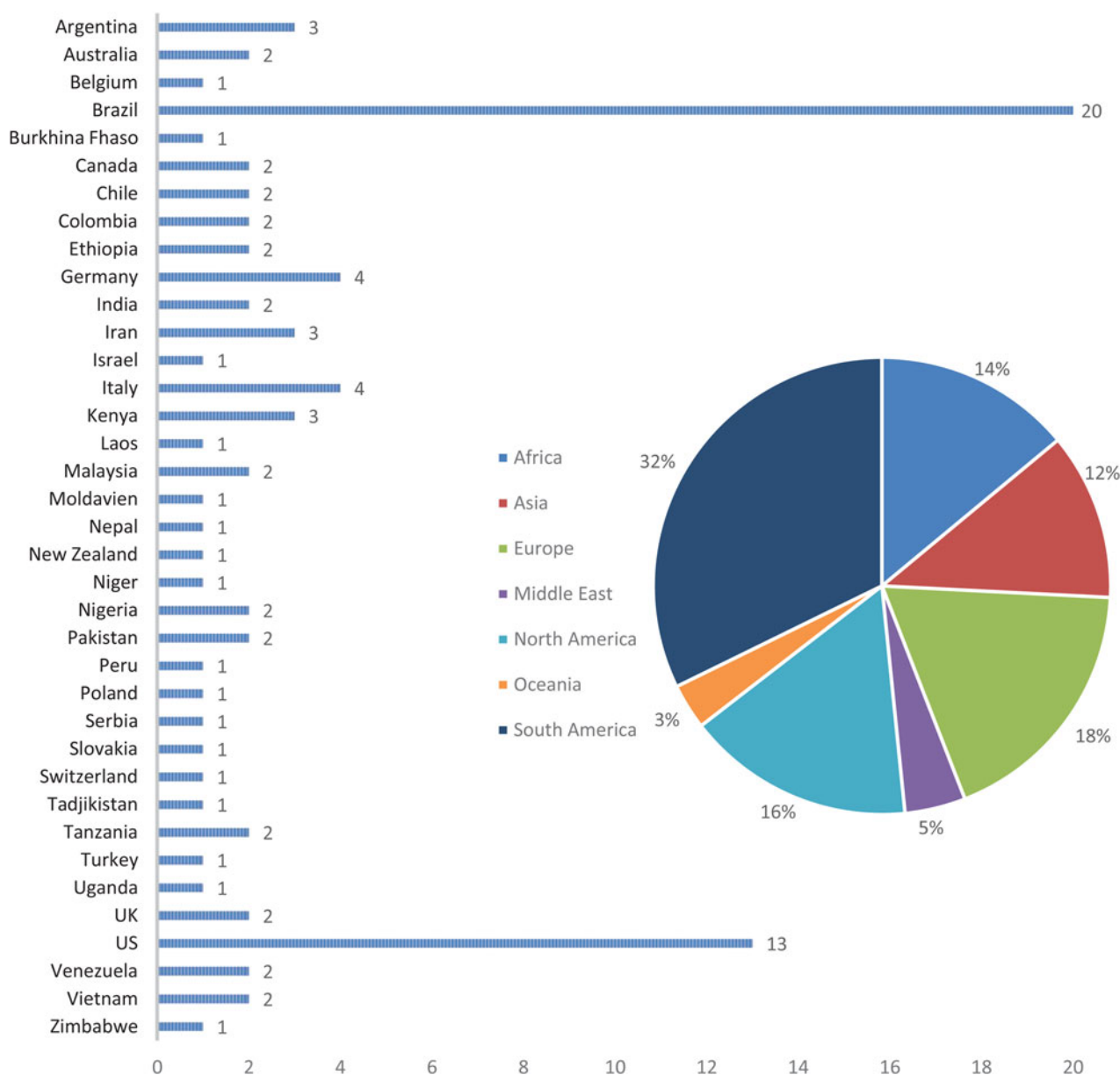
Fig. 2. Number of papers on zoonoses in urban animals in different countries that were included in a systematic review, as well as the proportion of studies conducted in the different continents.

among households with both goats and sheep, and it was concluded that the situation was out of control, also in urban areas (Jackson *et al.*, 2007). This was the largest study that sampled more than 13,000 livestock, but only 620 cattle and 176 small ruminants were said to have come from urban areas, with no definition of this being provided. Conurbations in Ethiopia had a herd prevalence of 8.6% (209 farms sampled), similar to the adjusted herd prevalence of 6.5% (177 farms sampled) in Kampala, Uganda (Makita *et al.*, 2011; Asmare *et al.*, 2013). Increasing age, larger herds, free grazing of cattle, and purchasing animals were identified as risk factors (Jackson *et al.*, 2007; Makita *et al.*, 2011; Asmare *et al.*, 2013). In a cross-sectional survey among ruminants in Niamey, Niger, it was found that cattle had higher seroprevalence than small ruminants, and the highest prevalence was found in rural areas, with lower in peri-urban and

lowest in urban (21.3, 5.1 and 3.3%, respectively) (Boukary *et al.*, 2010).

Campylobacter spp. *Campylobacter* spp. were studied in birds (wild birds or poultry) in four out of five papers. Positivity rates were frequently high, with 57% of backyard chicken flocks having *C. jejuni* in Canterbury, New Zealand (Anderson *et al.*, 2012). Studies in Morogoro, Tanzania, showed around 70% of both chicken (532 sampled) and crows (22 sampled) being positive, similar to 63% of 192 sampled ducks in Makurdi, Nigeria (Mdegela *et al.*, 2006; Akwuobu and Ofukwu, 2010). However, the prevalence seems to be able to vary locally, and one study in Canada geese in Greensboro, US, showed an average rate of 16%, while in one residential area, it was as high as 80% (Rutledge *et al.*, 2013). One proceeding studied rodents, but it was not possible to extract results from this.
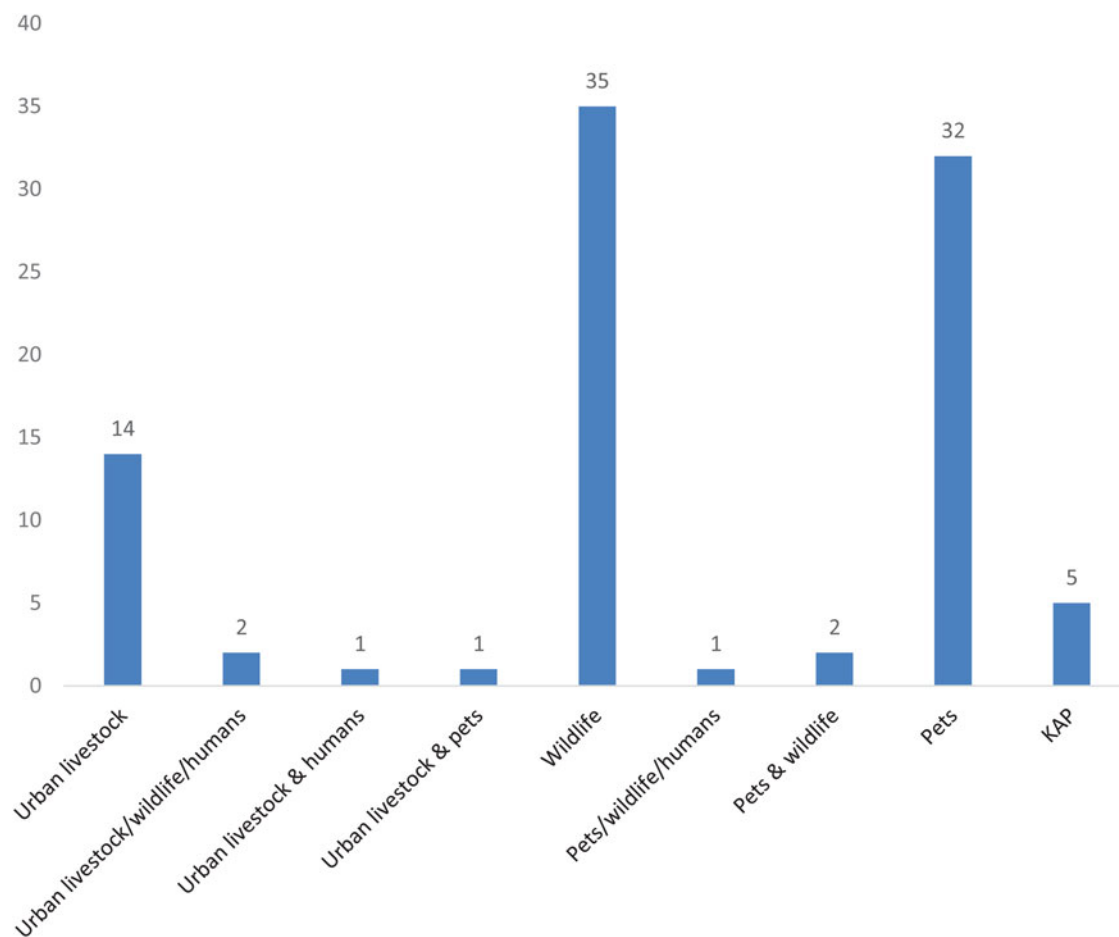
Fig. 3. Number of papers on different types of urban animals in a systematic review on zoonoses in urban animals. Knowledge, attitude, and practice (KAP) studies were broken into a separate category.

***Leptospira* spp.** Four of the seven studies on leptospirosis were conducted on dogs, three studies included rodents, and one of these included multiple species. Around 16% of dogs in Harare, Zimbabwe, and Curitiba, Brazil, were seropositive (Bier *et al.*, 2012; Dhliwayo *et al.*, 2012), while other cities in Brazil had between 7% seropositive in Ilheus, and 48% in Porto Alegre (Oliveira Lavinsky *et al.*, 2012; de Oliveira *et al.*, 2010), although sampling in the latter was targeted to high-risk dogs. Urban rodents also contribute to the risk of exposure. In Baltimore, US, 65% of rats were seropositive, while 15–32% of rodents in Vietnamese cities were seropositive (Easterbrook *et al.*, 2007; Koma *et al.*, 2013).

***Mycobacterium* spp.** One of the three studies on *Mycobacterium* spp. included abattoir diagnosis of cattle in Niamey, Niger, where 0.19% of carcasses had visible tuberculosis lesions (Boukary *et al.*, 2010). The other two studies used intradermal skin tests for diagnosis, and in peri-urban Faisalabad, Pakistan, 2.5% of buffaloes were found to be positive reactors (Arshad *et al.*, 2012), while 6.1% of cattle in peri-urban/urban Ouagadougou, Burkina Faso, were positive (Boussini *et al.*, 2012).

***Salmonella*.** In total, eight papers included studies about *Salmonella* spp., but one of these papers focused on assessing knowledge, attitudes, and practices. Four papers studied the prevalence of *Salmonella* spp in wild animals, recording positive rates of up to 11% in pigeons in Wroclaw, Poland (Piasecki, 2006). One study in dog and pigeon excretions in Italy failed to detect *Salmonella* spp.

Other bacteria. There were two publications each on *Bartonella* spp. and *Yersinia* spp., as well as one study focused on antimicrobial-resistant bacteria (Guenther *et al.*, 2012).

Parasites

***Cryptosporidium* spp.** Seven papers reported studies on cryptosporidiosis, four in wild animals, one in dogs, and two in livestock. A study on cattle in Nairobi, Kenya, found a higher prevalence in the dry compared to the wet season, with an individual prevalence being as high as 15% and herd prevalence 29% in the dry season (Kange'the *et al.*, 2012). The same study also found *Cryptosporidium* spp. in humans from households with dairy cattle, as well as in their neighbors (4 and 5%, respectively). Similar to the results on Giardia, Wang *et al.* (2012) found only *Cryptosporidium* spp. (3/129 tested) in dogs using dog parks. In wild animals, positive rates of 35 and 52% were reported in mice and rats, respectively, in Umuarama, Brazil (Kozerski *et al.*, 2012; Silva *et al.*, 2013). In Sydney, Australia, 133 possums were caught in traps and 11% were positive (Hill *et al.*, 2008).

Gastrointestinal helminthes, with focus on *Echinococcus* spp. In total, 25 papers reported on gastrointestinal helminthes in urban animals, of which nine specifically reported on echinococcosis/hydatidosis. Nine papers included wildlife and 12 dogs. Three papers stated that random sampling was used, and two of these explained the methodology. In some papers sampling was not directly from animals but from animal feces. All studies did
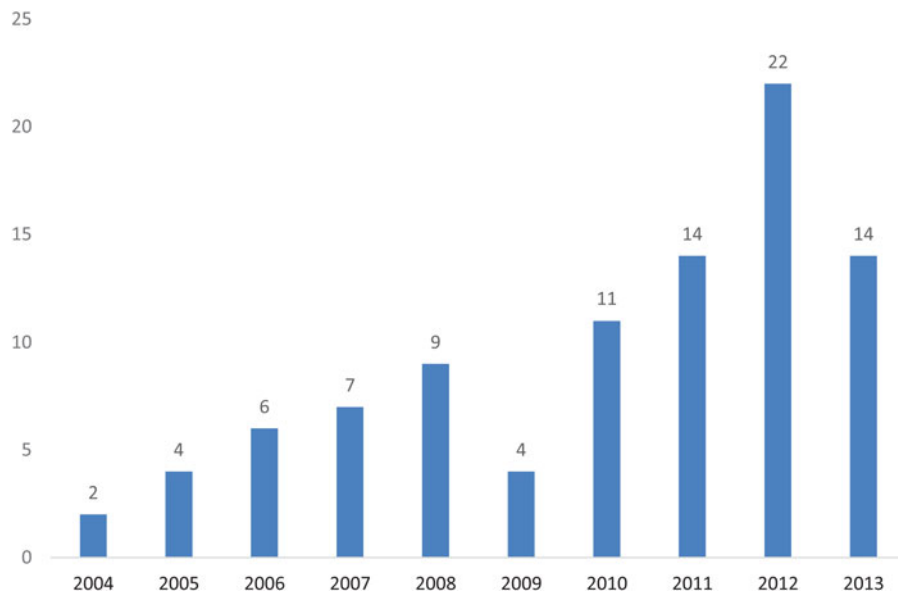
Fig. 4. Year of publication of the included papers on zoonoses in urban animals. The search included papers until November 2013.

find zoonotic parasites in urban animals, but there was a wide range of parasites discovered and varying positive rates. In red foxes in Geneva, Switzerland, it was found that the proportion positive for echinococcosis was lower in urban areas (31%, compared to 46% overall) (Fischer et al., 2005). Similar high levels of echinococcosis (25–30%) was found in cities in Argentina and Canada (Catalano et al., 2012; Liccioli et al., 2012; Casas et al., 2013). In contrast, no positive sample for *E. multilocularis* was found in 160 road-killed foxes in Brussels, Belgium (Brochier et al., 2007), and in a study on *E. granulosus* in dogs in Chile, it was found that urban dogs had a higher positive rate (11.7%, compared to 7.2% overall) (Acosta-Jamett et al., 2010).

Other parasitic species frequently studied include *Toxocara canis* and *Toxascaris leonina*, which are common dog parasites; however, occasional studies also look at urban livestock. In Mwanza city, Tanzania, higher infection rates with strongyles and coccidia in goats were found in the urban areas (Mhoma et al., 2011), and 95% infection rate with *Ascaris suum* was found in urban pigs in Ethiopia (Zewdneh et al., 2013). While dogs were more frequently found infected when they lived on the streets and in low-income areas, compared to house dogs and more affluent areas of the city (Martin and Demonte, 2008; Nikolić et al., 2008; Antolova et al., 2004), zoonotic parasites were also found in dogs that were not let onto the streets at all in Pinhais, Brazil (Martins et al., 2012).

Giardia **spp.** Out of the six papers reporting on *Giardia* spp., five were on dogs and one on coyote, and no study reported a probabilistic sampling. A Bayesian model for dogs in Pisa, Italy, estimated 29% of dogs were infected (*Papini et al., 2013*), while 19.8% of coyote carcasses in Calgary, Canada, and 17.3% of dogs in Botucatu, Brazil were positive (Liccioli et al., 2012; Silva et al., 2012). A study from the US found only 5 dogs positive out of 129, and all dogs that were positive were using dog parks, identified as the main risk factor (Wang et al., 2012).

Leishmania **spp.** All the six studies included on *Leishmania* spp. had been conducted on dogs in Brazil, two with purposive sampling and four with unknown sampling methodology. Different detection methods yielded different estimates in urban prevalence, with a serological study in Cuiabá having the highest

proportion positive of 27% in urban dogs (Mestre et al., 2011), but the paper contained no information about sampling methodology. In comparison, a study in Dias D'Ávila found only 2.5% positive dogs in the city and 29.9% positive in rural areas, and concluded that leishmaniasis was significantly more common in the countryside (de Oliveira et al., 2010).

Toxoplasma: Of the eight papers reporting on *Toxoplasma gondii*, two were on pets (dogs and stray cats), and the rest on wildlife, and only one paper reported on random selection, but without explaining methodology. Among the dogs sampled in Botucato, Brazil, 33.1% had antibodies against *Toxoplasma* (Langoni et al., 2006), whereas only 5% of pigeons in the same country had it (de Lima et al., 2011). Contrastingly, 75.6% of pigeons were seropositive in Wroclaw, Poland, (Piasecki, 2006).

Other parasites. Other parasites studied included the vector-borne *Trypanosoma cruzi* and *Babesia* spp., miscellaneous protozoan parasites (*Blastocystis, Neospora*), and macroparasites (*Trichinella, Tunga penetrans, Paragonium*), bacterial (two publications each on *Bartonella* and *Yersinia*), viruses (reoviruses, picobirnaviruses, arenaviruses, hantaviruses). One study focused on antimicrobial-resistant bacteria (Guenther et al., 2012).

Discussion

This review used a number of search strings to screen databases to identify papers published on the topics of zoonotic infections in animals in urban areas. While research solely on human disease, prevalence or incidence was excluded, papers were included on peridomestic wildlife and domestic animals, including pets and livestock, and it was found that most studies were about pets and urban wildlife, while urban livestock was studied more seldom. This may be due to the fact that the importance of urban livestock keeping often has been underestimated when it comes to both their contribution to food security and nutrition as well as to pathogen transmission and disease emergence. However, there are also still prevailing perceptions that livestock keeping is mainly a rural livelihood. Also, it may be due to difficulties in researching an animal husbandry practice that is informal or illegal in many countries, and when authorities are not willing
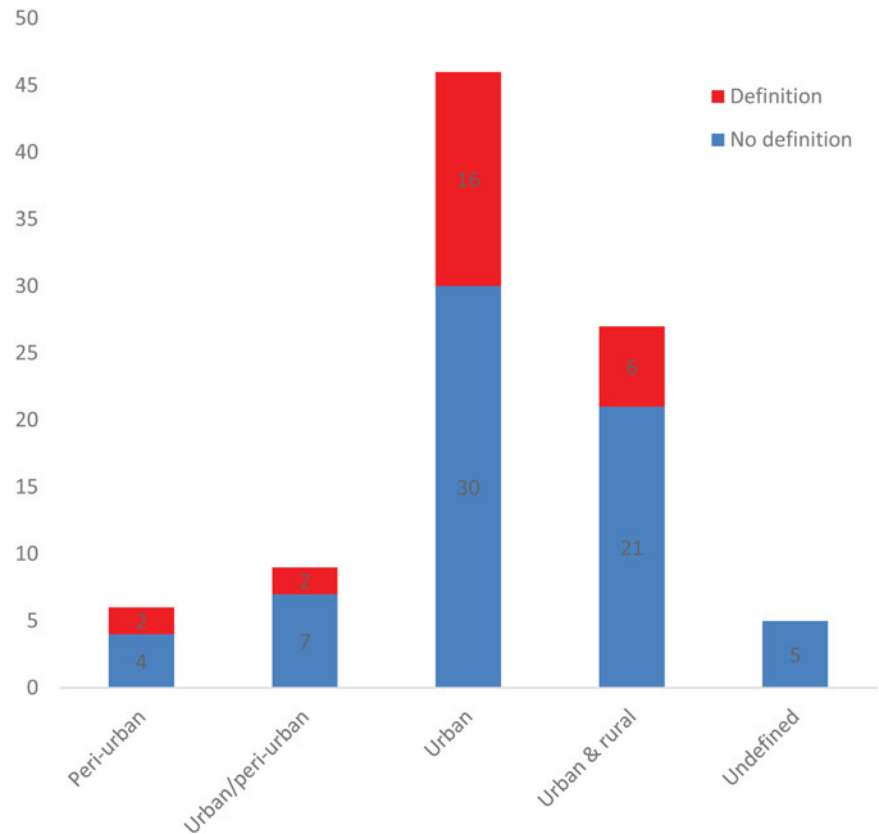
Fig. 5. Number of papers based on the classification of study area, and if the paper contained a definition or a description of how the area was classified.

to admit the extent of such practices (Grace *et al.*, 2015). The keeping of urban livestock combined with increased human population densities may facilitate spread of diseases, and urbanization is considered one of the drivers behind disease emergence due to the extensive interface and the high number of susceptible and infectious individuals that may meet and interact (Lindahl and Grace, 2015).

It is evident in the papers reviewed that when zoonotic pathogens are looked for, they are often detected in urban areas, and most studies conclude that zoonoses are a threat to human inhabitants. One may, however, suspect that there is a publication bias against studies looking for zoonotic pathogens in urban environments and not finding them, as negative results are less likely to get published (Dickersin, 1990; Dirnagl and Lauritzen, 2010; Koricheva *et al.*, 2013). One rare exception included in this review is the report by Kohls *et al.* (2011) showing negative results for influenza. However, this same paper also reported on the presence of paramyxovirus, which may have facilitated its publication.

Many low-income countries with large and rapidly expanding cities were not represented in this screening, or were represented only by very few publications. It is remarkable that only 5 papers each came from the low- and middle-income countries in South and Southeast Asia, regions with dense populations in multiple mega-cities, with more than 10 million people. Similarly, countries such as Russia, China, and South Africa were not represented, possibly because our search strings did not detect them. However, searching a database like PubMed with the search terms zoonotic or zoonoses, urban and Russia, also yielded few results. There may be a tendency to publish in national journals in some countries, and thus the results are not available for the international research community which could explain why our

search did not retrieve the articles. However, it may also be an indication of that the topic of urban animals and zoonoses has long had a very low priority. Considering that sub-Saharan Africa is foreseen to be responsible for a large part of the population growth in the future, with many cities with high growth rate and often extensive informal settlements (Gerland *et al.*, 2014; Bloom, 2011), it is worrisome that not more than 13 papers were found relating to zoonoses in African cities. Scarcity on published papers on zoonoses in Africa has however been noted before, and may have multiple reasons. For example, difficulties for scientists to get research published in journals accessible online, or low priority among research donors (Alonso *et al.*, 2016).

The most frequently studied pathogens were gastrointestinal helminths, followed by the diarrheal pathogens *Salmonella*, *Giardia*, and *Campylobacter*. The reasons for selection of these pathogens may be the focus on certain host species, or more pragmatic ones, such as the relative ease to collect fecal samples or a straightforward diagnostic methodology. However, in OIE's annual report on human cases of zoonosis (OIE 2017), brucellosis and leptospirosis, which are sparsely found in this review, were the diseases reported from most countries in 2015. On the other hand, with respect to the number of human cases, the diarrheal diseases salmonellosis and campylobacteriosis seems to be the most frequent. Notably, also the large Global Burden of Disease Study 2015, points out diarrheal diseases as the infectious disease contributing to most disability-adjusted life-years (DALYs) (GBD 2015 DALYs and HALE Collaborators, 2016). Among the major zoonoses, the WHO deals with (WHO 2017), food-borne zoonoses and leptospirosis are also found in this review. In contrast, other WHO-prioritized zoonoses like anthrax

Table 2. Number of papers within each pathogen group and the host species and countries of the studies

Pathogen	Papers	Species studied	Geographic study locations
Avian influenza virus/ Influenza A	4	Bats (1), pigeons (1), knowledge, attitudes and practices (2)	Germany (2), Turkey (1), Lao PDR (1)
Brucella spp.	5	Cattle (4), cattle and small ruminants (1)	Burkina Faso (1), Ethiopia (1), Niger (1), Tajikistan (1), Uganda (1)
Campylobacter spp.	5	Chicken (2), ducks (1), crows (1), geese (1), rodents (1)	New Zealand (1), Nigeria (1), Tanzania (1), UK (1), USA (1)
Cryptosporidium spp.	7	Rodents (2), crows (1), possum (1), dogs (1), pigs (1), cattle (1)	Brazil (2), Australia (1), Ethiopia (1), Kenya (1), Malaysia (1), USA (1)
Gastrointestinal helminths	25	Dogs (12), multiple livestock species (2), pig (1), goats (1), fish (1), rodents (3), foxes (3), coyotes (2), raccoons (1).	Argentina (3), Brazil (3), Canada (2), Belgium (1), Chile (1), Ethiopia (1), India (1), Iran (1), Italy (1), Malaysia (1), Moldavia (1), Nigeria (1), Peru (1), Serbia (1), Slovakia (1), Switzerland (1), Tanzania (1), USA (1), Vietnam (1)
Echinococcus spp.	9	Dogs (4), multiple livestock (1), coyotes (2), foxes (2)	Canada (2), Argentina (1), Chile (1), Belgium (1), India (1), Iran (1), Peru (1), Switzerland (1)
Giardia spp.	6	Dogs (5), coyote (1)	US (2), Brazil (1), Canada (1), Italy (1), Serbia (1)
Leishmania spp.	6	Dogs (6)	Brazil (6)
Leptospira spp.	7	Rodents (2), dogs (4), multiple species (1)	Brazil (4), Chile (1), USA (1), Vietnam (1), Zimbabwe (1)
Mycobacterium spp.	3	Ruminant livestock (3)	Burkina Faso (1), Niger (1), Pakistan (1)
Rabies virus	6	Dogs (3), bats (2), skunks (1)	USA (2), Venezuela (2), Brazil (1), Colombia (1)
Salmonella spp.	8	Rodents (2), wild birds (4), dogs (1), bats (1), knowledge, attitudes and practices (1)	USA (2), Poland (1), Germany (2), Italy (1), Malaysia (1), UK (1)
Toxoplasma spp.	8	Cats (1), dogs (1), pigeons (2), rodents (1), possums (1), opossums (1), badgers (1)	Brazil (3), Australia (1), Iran (1), Poland (1), UK (1), USA (1)

Echinococcus is included in the group gastrointestinal helminths, but also reported on a separate row.

and prion diseases are not found at all in the review. It is interesting to note that for some of the food-borne pathogens, the majority of the studies found in this review were conducted in high-income countries, while the burden of these diseases is proportionally much higher in low-income countries (Engels and Savioli, 2006). In summary, the literature found here on urban zoonoses deals with several of the pathogens that may be regarded as the most important zoonotic pathogens globally. However, at the same time, some of the important zoonotic pathogens are just sparsely studied or not studied at all in urban animals, or are not studied in countries where the burden is high.

This review has several limitations, and the narrow scope of only including papers written in English and only search in international databases, likely made some countries under-represented here. While we used some very general search terms, such as, 'Urban AND ('Animal Diseases' OR 'Human Diseases') AND Health AND Cities', we did not include the names of specific diseases, nor all hosting animal species, which may have contributed to less consideration of some relevant studies. However, the main purpose of this review was to get an overview of where most of the peer-reviewed research has been conducted and where the research focus has been, and we believe that this was still achieved. One interesting finding was that, in spite of many search terms being aimed specifically at picking up studies on urban livestock, this topic was very much under-represented, which further indicates a need for covering that knowledge gap.

In conclusion, this review points out three areas where science-based knowledge is limited. First, with respect to the traditional research focus on zoonoses in livestock in rural areas, we may be at a point where we need to shift focus towards the crowded urban settings where we may see hot-spots for disease emergence in the future. Second, it is worrisome that so few studies are from the rapidly expanding cities in low- and middle-income countries, where urban livestock keeping is far more prominent than in high-income countries. Third, there are arguments to consider other zoonotic pathogens in future studies on zoonoses in urban animals. Overall, there are significant research gaps that should be filled in order to mitigate risks of emergence of zoonoses from urban animals.

References

Acosta-Jamett G, Cleaveland S, Bronsvoort BM, Cunningham AA, Bradshaw H and Craig PS (2010) *Echinococcus granulosus* infection in domestic dogs in urban and rural areas of the Coquimbo region, north-central Chile. *Veterinary Parasitology* **169**, 117–122.

Akwuobu CA and Ofukwu RA (2010) *Campylobacter jejuni* in duck faeces around drinking water sources in Makurdi, North-Central Nigeria: public

health implication. *Tanzania Veterinary Journal* **27**, 21–26. Available at http://ajol.info/index.php/tvj/article/viewFile/62761/50674.

Alonso S, Lindahl J, Roesel K, Traore SG, Yobouet BA, Ndour APN, Carron M and Grace D (2016) Where literature is scarce: observations and lessons learnt from four systematic reviews of zoonoses in African countries. *Animal Health Research Reviews* **17**, 28–38. Available at http://www.journals.cambridge.org/abstract_S1466252316000104 (Accessed 21 July 2016).

Anderson DR (2001) The need to get the basics right in wildlife field studies. *Wildlife Society Bulletin* **29**, 1294–1297. Available at http://www.jstor.org/stable/3784156?seq=1#page_scan_tab_contents.

Anderson J, Horn BJ and Gilpin BJ (2012) The prevalence and genetic diversity of *Campylobacter* spp. in domestic 'backyard' poultry in Canterbury, New Zealand. *Zoonoses and Public Health* **59**, 52–60.

Antolova D, Reiterova K, Miterpakova M, Stanko M and Dubinsky P (2004) Circulation of *Toxocara* spp. in suburban and rural ecosystems in the Slovak Republic. *Veterinary Parasitology* **126**, 317–324.

Arshad M, Ifrahim M, Ashraf M, Rehman SU and Khan HA (2012) Epidemiological studies on tuberculosis in buffalo population in villages around Faisalabad. *JAPS, Journal of Animal and Plant Sciences* **22**, 246–249.

Asmare K, Sibhat B, Molla W, Ayelet G, Shiferaw J, Martin AD, Skjerve E and Godfroid J (2013) The status of bovine brucellosis in Ethiopia with special emphasis on exotic and cross bred cattle in dairy and breeding farms. *Acta Tropica* **126**, 186–192.

Bakiray Küçükkaya S, Erbaydar Tugrul, Stöhr C, Edirne T, Avci DK, Dagkara B, Aslan M, Oner A, Bay A, Arslan S, Sarikaya O, Erbaydar T, Sur H, Tasdemir M, Cekin M, Olsen S, Laosiritaworn Y, Pattanasin S, Capua I, Mutinelli F, Poza M, Oyewo I, Raufu M, Ogunlana O, Oyedele T, Koch G, Elbers A, Kruk M, Cevizci S and Erginoz E (2011) Behaviors and experiences of poultry owners in Dogubayazit whose poultry were culled during the avian influenza epidemic. *European Journal of Public Health* **22**, 174–177. Available at http://www.ncbi.nlm.nih.gov/pubmed/21382973 (Accessed 22 June 2016).

Barennes H, Harimanana AN, Lorvongseng S, Ongkhammy S, Chu C, Ly S, Kerkhove M Van, Holl D, Froehlich Y, Vong S, Puthavathana P, Sangsiriwut K, Korkusol A, Pooruk P, Auewarakul P, Pittayawanganon C, Sutdan D, Kitphati R, Sawanpanyalert P, Phommasack B, Bounlu K, Ungchusak K, Webster R, Guan Y, Poon L, Krauss S, Webby R, Govorkovai E, Peiris M, Barennes H, Martinez-Aussel B, Vongphrachanh P, Strobel M, Takeuchi M, Lau J, Kim J, Tsui H, Griffiths S, Zwart O De, Veldhuijzen I, Elam G, Aro A, Abraham T, Bishop G, Richardus J, Brug J, Mcleod A, Morgan N, Prakash A, Hinrichs J, Peltz R, Galit A, Ventura-Gabay M and Bar-Dayan Y (2010) Paradoxical risk perception and behaviours related to Avian Flu outbreak and education campaign, Laos. *BMC Infectious Diseases* **10**, 294. Available at http://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-10-294 (Accessed 10 June 2016).

Bier D, Martins-Bede FT, Morikawa VM, Ullmann LS, Kikuti M, Langoni H, Canever RJ, Biondo AW and Molento MB (2012) Spatial distribution of seropositive dogs to *Leptospira* spp. and evaluation of leptospirosis risk factors using a decision tree. *Acta Scientiae Veterinariae* **40**, 1054.

Bloom DE (2011) 7 billion and counting. *Science* **333**, 562–569. Available at http://www.sciencemag.org/content/333/6042/562.abstract.

Boukary AR, Saegerman C, Rigouts L, Matthys F, Berkvens D and Thys E (2010) Preliminary results of the study on zoonotic brucellosis and tuberculosis in Niamey, Conference proceeding: Globalization of Tropical Animal Diseases and Public Health Concerns; proceedings of 13th AITVM 2010 International Conference, 23-26 August 2010, Bangkok, Thailand, pp. 22–24.

Boussini H, Traore A, Tamboura HH, Bessin R, Boly H and Ouedraogo A (2012) [Prevalence of tuberculosis and brucellosis in urban and peri-urban dairy cattle farms in Ouagadougou, Burkina Faso]. *Revue Scientifique et Technique* **31**, 943–951.

Bradley CA and Altizer S (2007) Urbanization and the ecology of wildlife diseases. *Trends in Ecology & Evolution* **22**, 95–102.

Brochier B, De Blander H, Hanosset R, Berkvens D, Losson B and Saegerman C (2007) Echinococcus multilocularis and Toxocara canis in urban red foxes (Vulpes vulpes) in Brussels, Belgium. *Preventive Veterinary Medicine* **80**, 35–73.

Casas N, Costas Otero S, Cespedes G, Sosa S and Santillan G (2013) [Coproantigens detection for the diagnosis of canine Echinococcosis in the border area of La Quiaca-Villazon]. *Revista Argentina de Microbiologia* **45**, 154–159.

Catalano S, Lejeune M, Liccioli S, Verocai GG, Gesy KM, Jenkins EJ, Kutz SJ, Fuentealba C, Duignan PJ and Massolo A (2012) *Echinococcus multilocularis* in urban coyotes, Alberta, Canada. *Emerging Infectious Diseases* **18**, 1625–1628.

Cutler SJ, Fooks AR and Van Der Poel WHM (2010) Public health threat of new, reemerging, and neglected zoonoses in the industrialized world. *Emerging Infectious Diseases* **16**, 1–7.

de Lima VY, Langoni H, da Silva AV, Pezerico SB, de Castro APB, da Silva RC, Araujo JP and Araújo JP (2011) *Chlamydophila psittaci* and *Toxoplasma gondii* infection in pigeons (*Columba livia*) from Sao Paulo State, Brazil. *Veterinary Parasitology* **175**, 9–14.

de Oliveira L C P, de Araujo RR, Alves CR, Mouta-Confort E, Lopez JA and de Mendonca-Lima FW (2010) Seroprevalence and risk factors for canine visceral leishmaniasis in the endemic area of Dias D'Avila, State of Bahia, Brazil. *Revista Da Sociedade Brasileira De Medicina Tropical* **43**, 400–404. Available at http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0037-86822010000400013&lng=en&nrm=iso&tlng=en (Accessed 10 June 2016).

De Zeeuw H and Lock K (2000) Urban and Periurban Agriculture, Health and Environment. Discussion paper. In FAO-ETC/RUAF electronic conference 'Urban and Periurban Agriculture on the Policy Agenda', http://www.fao.org/urbanag/, 8/21-9/30.

Dhliwayo S, Matope G, Marabini L, Dutlow K and Pfukenyi DM (2012) Seroprevalence of leptospirosis in dogs in urban Harare and selected rural communities in Zimbabwe. *Onderstepoort Journal of Veterinary Research* **79**, 6. Available at: http://www.ojvr.org/index.php/ojvr/article/view/447 (Accessed 10 June 2016).

Dickersin K (1990) The existence of publication bias and risk factors for its occurrence. *JAMA: The Journal of the American Medical Association*, **263**, 1385. Available at http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.1990.03440100097014 (Accessed 5 December 2016).

Dirnagl U and Lauritzen M (2010) Fighting publication bias: introducing the Negative Results section. *Journal of Cerebral Blood Flow and Metabolism: Official Journal of the International Society of Cerebral Blood Flow and Metabolism* **30**, 1263–1264. Available at http://www.ncbi.nlm.nih.gov/pubmed/20596038 (Accessed 5 December 2016).

Easterbrook JDD, Kaplan JBB, Vanasco NBB, Reeves WKK, Purcell RHH, Kosoy MYY, Glass GEE, Watson J and Klein SLL (2007) A survey of zoonotic pathogens carried by Norway rats in Baltimore, Maryland, USA. *Epidemiology and Infection* **135**, 1192–1199. Available at http://www.journals.cambridge.org/abstract_S0950268806007746 (Accessed 10 June 2016).

Engels D and Savioli L (2006) Reconsidering the underestimated burden caused by neglected tropical diseases. *Trends in Parasitology* **22**, 363–366.

Fischer C, Reperant LA, Weber JM, Hegglin D and Deplazes P (2005) *Echinococcus multilocularis* infections of rural, residential and urban foxes (*Vulpes vulpes*) in the canton of Geneva, Switzerland. *Parasite* **12**, 339–346. Available at http://www.parasite-journal.org/10.1051/parasite/2005124339 (Accessed 22 June 2016).

Fuentes B, Panunzio A, Larreal Y, Leal J, Villarroel F, Parral I, Velasco D and Prieto Y (2008) Presence of urban rabies in Zulia state, Venezuela. Years 1996–2006. *Investigacion Clinica* **49**, 487–498.

GBD 2015 DALYs and HALE Collaborators (2016) Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990–2015. *Lancet* **388**, 1603–1658. Available at https://helda.helsinki.fi/handle/10138/172720 (Accessed 3 June 2017).

Gerland P, Raftery AE, Sevčíková H, Li N, Gu D, Spoorenberg T, Alkema L, Fosdick BK, Chunn J, Lalic N, Bay G, Buettner T, Heilig GK and Wilmoth J (2014) World population stabilization unlikely this century. *Science* **346**, 234–237. Available at http://www.sciencemag.org/content/346/6206/234.abstract (Accessed 19 September 2014).

Grace D, Lindahl J, Correa M and Kakkar M (2015) Urban livestock keeping. In de Zeeuw H and Drechsel P (eds), *Cities and Agriculture: Developing Resilient Urban Food Systems*. New York: Routledge, pp. 255–284. Available at: https://books.google.com/books?hl=en&lr=&id=2O6PCgAAQBAJ&pgis=1 (Accessed 15 February 2016).

Gubler DJ (1996) The global resurgence of arboviral diseases. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **90**, 449–451. Available at http://www.sciencedirect.com/science/article/B75GP-4BY30XS-3J/2/ef600fedec87bc9b6257e1857048df07.

Guenther S, Bethe A, Fruth A, Semmler T, Ulrich RG, Wieler LH and Ewers C (2012) Frequent combination of antimicrobial multiresistance and extraintestinal pathogenicity in *Escherichia coli* isolates from urban rats (*Rattus norvegicus*) in Berlin, Germany. *Plos One* **7**, e50331. Available at http://dx.plos.org/10.1371/journal.pone.0050331 (Accessed 22 June 2016).

Hill NJ, Deane EM and Power ML (2008) Prevalence and genetic characterization of *Cryptosporidium* isolates from common brushtail possums (*Trichosurus vulpecula*) adapted to urban settings. *Applied and Environmental Microbiology* **74**, 5549–5555. Available at http://aem.asm.org/cgi/doi/10.1128/AEM.00809-08 (Accessed 22June 2016).

Jackson R, Ward D, Kennard R, Amirbekov M, Stack J, Amanfu W, El-Idrissi A and Otto H (2007) Survey of the seroprevalence of brucellosis in ruminants in Tajikistan. *Veterinary Record* **161**, 476–482. Available at http://www.ncbi.nlm.nih.gov/pubmed/17921439 (Accessed 22 June 2016).

Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL and Daszak P (2008) Global trends in emerging infectious diseases. *Nature* **451**, 990–993. Available at http://dx.doi.org/10.1038/nature06536 http://www.nature.com/nature/journal/v451/n7181/suppinfo/nature06536_S1.html.

Kange'the E, McDermott B, Grace D, Mbae C, Mulinge E, Monda J, Nyongesa C, Ambia J and Njehu A (2012) Prevalence of cryptosporidiosis in dairy cattle, cattle-keeping families, their non-cattle-keeping neighbours and HIV-positive individuals in Dagoretti Division, Nairobi, Kenya. *Tropical Animal Health and Production* **44**(suppl. S1), pp. 1–6. Available at http://link.springer.com/10.1007/s11250-012-0201-6 (Accessed 6 June 2013).

Kohls A, Lüschow D, Lierz M and Hafez HM (2011) Influenza A virus monitoring in urban and free-ranging pigeon populations in Germany, 2006–2008. *Avian Diseases* **55**, 447–450. Available at http://www.bioone.org/doi/abs/10.1637/9567-100710-ResNote.1 (Accessed 27 September 2016).

Koma T, Yoshimatsu K, Yasuda SP, Li T, Amada T, Shimizu K, Isozumi R, Mai LTQ, Hoa NT, Nguyen V, Yamashiro T, Hasabe F and Arikawa J (2013) A survey of rodent-borne pathogens carried by wild *Rattus* spp. in Northern Vietnam. *Epidemiology and Infection* **141**, 1876–1884. Available at http://www.journals.cambridge.org/abstract_S0950268812002385 (Accessed 22 June 2016).

Koricheva J, Gurevitch J and Mengersen KL (2013) *Handbook of Meta-Analysis in Ecology and Evolution*. New Jersey, US: Princeton University Press.

Kozerski ND, Caldato LD, de A Ceranto JB, von Söhsten AL, Messa V and da Silva AV (2012) Occurrence of *Cryptosporidum* sp in sinantropic *Rattus* (Fischer, 1803) and *Mus* (Linnaeus, 1758) captured in the urban area of Umuarama, PR, Brazil. *Arquivos de Ciências Veterinárias e Zoologia da UNIPAR* **15**, 133–136. Available at http://revistas.unipar.br/veterinaria/article/view/4216/2625 (Accessed 22 June 2016).

Langoni H, Modolo JR, Pezerico SB, Silva RC, Castro APB, da Silva AV and Padovani CR (2006) Serological profile of anti-*Toxoplasma gondii* antibodies in apparently healthy dogs of the city of Botucatu, Sao Paulo State, Brazil. *Journal of Venomous Animals and Toxins Including Tropical Diseases* **12**, 142–148. Available at http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-91992006000100012&lng=en&nrm=iso&tlng=en (Accessed 22 June 2016).

Liccioli S, Catalano S, Kutz SJ, Lejeune M, Verocai GG, Duignan PJ, Fuentealba C, Hart M, Ruckstuhl KE and Massolo A (2012) Gastrointestinal parasites of coyotes (*Canis latrans*) in the metropolitan area of Calgary, Alberta, Canada. *Canadian Journal of Zoology* **90**, 1023–1030. Available at http://www.nrcresearchpress.com/doi/abs/10.1139/z2012-070 (Accessed 27 September 2016).

Lindahl JF, Ståhl K, Chirico J, Boqvist S, Thu HTV and Magnusson U (2013) Circulation of Japanese encephalitis virus in pigs and mosquito vectors within Can Tho City, Vietnam. *PLoS Neglected Tropical Diseases* **7**, 1–8. Available at http://dx.doi.org/10.1371/journal.pntd.0002153.

Lindahl JF and Grace D (2015) The consequences of human actions on risks for infectious diseases: a review. *Infection Ecology & Epidemiology*, **5**, 1–11. Available at http://www.infectionecologyandepidemiology.net/index.php/iee/article/view/30048/xml_28 (Accessed 27 November 2015).

Makita K, Fèvre EM, Waiswa C, Eisler MC, Thrusfield M and Welburn SC (2011) Herd prevalence of bovine brucellosis and analysis of risk factors in cattle in urban and peri-urban areas of the Kampala economic zone, Uganda. *BMC Veterinary Research* **7**, 60. Available at http://bmcvetres.biomedcentral.com/articles/10.1186/1746-6148-7-60 (Accessed 27 September 2016).

Martin UO and Demonte MA (2008) Urban contamination with zoonotic parasites in the central region of Argentina. *Medicina (B Aires)* **68**, 363–366.

Martins CM, Barros C da C de, Bier D, Marinho AP, Figueiredo JMG, Hoffmann JL, Molento MB and Biondo AW (2012) Dog parasite incidence and risk factors, from sampling after one-year interval, in Pinhais, Brazil. *Revista Brasileira de Parasitologia Veterinária* **21**, 101–106. Available at http://www.cbpv.com.br/rbpv/documentos/2122012/rbpv_v21n2_a05.pdf.

Mayes BC, Wilson PJ, Oertli EH, Hunt PR and Rohde RE (2013) Epidemiology of rabies in bats in Texas (2001–2010). *Journal of the American Veterinary Medical Association* **243**, 1129–1137.

Mdegela RH, Nonga HE, Ngowi HA and Kazwala RR (2006) Prevalence of thermophilic *Campylobacter* infections in humans, chickens and crows in Morogoro, Tanzania. *Journal of Veterinary Medicine. B, Infectious Diseases and Veterinary Public Health* **53**, 116–121. Available at http://doi.wiley.com/10.1111/j.1439-0450.2006.00926.x (Accessed 27 September 2016].

Mestre GL da C, Ribeiro ALM, Miyazaki RD, Rodrigues JSV, Almeida A do BPF de, Sousa VRF and Missawa NA (2011) Phlebotomine sand flies and canine infection in areas of human visceral leishmaniasis, Cuiabá, Mato Grosso. *Revista Brasileira de Parasitologia Veterinária* **20**, 228–234. Available at http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1984-29612011000300010&lng=en&nrm=iso&tlng=en (Accessed 27 September 2016).

Mhoma J, Kanyari P and Kagira J (2011) The prevalence of gastro-intestinal parasites in goats in urban and peri-urban areas of Mwanza city, Tanzania. *Scientica Parasitologica* **12**, 191–196.

Midmore DJ and Jansen HGP (2003) Supplying vegetables to Asian cities: is there a case for peri-urban production? *Food Policy* **28**, 13–27. Available at: http://www.sciencedirect.com/science/article/pii/S0306919202000672.

Moher D, Liberati A, Tetzlaff J, Altman DG and the PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*, **151**, 264–269.

Morse SS (1995) Factors in the emergence of infectious diseases. *Emerging Infectious Diseases*, 1.

Mougeot L (2000) Urban agriculture: Definition, presence, potentials and risks. In Bakker N (ed.), *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*. Feldafing, Germany: Deutsche Stiftung fuer internationale Entwicklung (DSE), pp. 1–42.

Mühldorfer K, Speck S, Kurth A, Lesnik R, Freuling C, Müller T, Kramer-Schadt S and Wibbelt G (2011) Diseases and causes of death in European bats: dynamics in disease susceptibility and infection rates A. R. Fooks, ed. *PLoS ONE*, **6**, e29773. Available at http://dx.plos.org/10.1371/journal.pone.0029773 (Accessed 27 September 2016).

Nikolić A, Dimitrijević S, Katić-Radivojević S, Klun I, Bobić B and Djurković-Djaković O (2008) High prevalence of intestinal zoonotic parasites in dogs from Belgrade, Serbia — short communication. *Acta Veterinaria Hungarica* **56**, 335–340. Available at http://www.akademiai.com/doi/abs/10.1556/AVet.56.2008.3.7 (Accessed 27 September 2016).

Nugent R (2000) The impact of urban agriculture on the household and local economies. In Bakker N (ed.), *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda*. Feldafing, Germany: Deutsche Stiftung fuer internationale Entwicklung (DSE), pp. 67–97.

Oertli EH, Wilson PJ, Hunt PR, Sidwa TJ and Rohde RE (2009) Epidemiology of rabies in skunks in Texas. *Journal of the American Veterinary Medical Association*, **234**, 616–620. Available at http://

avmajournals.avma.org/doi/abs/10.2460/javma.234.5.616 (Accessed September 27, 2016).

OIE (2017) Zoonotic diseases in humans 2015. Available at https://www.oie.int/wahis_2/public/wahid.php/Countryinformation/Zoonoses%0A%0A (Accessed 30 May 2017).

Oliveira Lavinsky M, Said RA, Strenzel GMR and Langoni H (2012) *Seroprevalence of anti-Leptospira spp. antibodies in dogs in Bahia, Brazil.* Preventive Veterinary Medicine 106, 79–84.

Oliveira ST, Messick JB, Biondo AW, Santos AP dos, Stedile R, Dalmolin ML, Guimaraes AM de S, Mohamed AS, Riediger IN and González FHD (2012) Exposure to *Leptospira* spp. in sick dogs, shelter dogs and dogs from an endemic area: points to consider. *Acta Scientiae Veterinariae* 40, 1056. Available at http://www.ufrgs.br/actavet/40-3/PUB1056.pdf.

Páez A, Rey G, Agudelo C, Dulce Á., Parra E, Díaz-Granados H, Heredia D and Polo L (2009) Outbreak of urban rabies transmitted by dogs in Santa Marta, northern Colombia. *Biomedica: Revista del Instituto Nacional de Salud* 29, 424–436.

Papini R, Carreras G, Marangi M, Mancianti F and Giangaspero A (2013) Use of a commercial enzyme-linked immunosorbent assay for rapid detection of *Giardia duodenalis* in dog stools in the environment: a Bayesian evaluation. *Journal of Veterinary Diagnostic Investigation* 25, 418–422. Available at http://www.ncbi.nlm.nih.gov/pubmed/23604261 (Accessed 27 September 2016).

Piasecki T (2006) Evaluation of urban pigeon (*Columba livia* f. *urbana*) health status in relation to their threat to human health. *Medycyna Weterynaryjna* 62, 531–535.

Prieto Y, Garcia A, Sanchez E, Medina A and de Vale MO (2006) Risk factors associated to the occurrence of urban rabies on Maracaibo county, Zulia state, Venezuela. *Revista Cientifica-Facultad De Ciencias Veterinarias* 16, 165–175.

Rae AN (1998) The effects of expenditure growth and urbanisation on food consumption in East Asia: a note on animal products. *Agricultural Economics* 18, 291–299. Available at http://www.sciencedirect.com/science/article/B6T3V-3TG6NJ2-1/2/f2cd79cc1a9516856518b97e73f50bbc.

Rutledge ME, Siletzky RM, Gu W, Degernes LA, Moorman CE, DePerno CS and Kathariou S (2013) Characterization of *Campylobacter* from resident Canada Geese in an urban environment. *Journal of Wildlife Diseases* 49, 1–9. Available at: http://www.bioone.org/doi/10.7589/2011-10-287 [Accessed September 27, 2016].

Satterthwaite D, McGranahan G and Tacoli C (2010) Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society B-Biological Sciences* 365, 2809–2820.

Saxena SK, Tiwari S, Saxena R, Mathur A and Nair MPN (2011) Japanese encephalitis: an emerging and spreading arbovirosis. In Růžek D (ed.), *Flavivirus Encephalitis*. Rijeka, Croatia: InTech, pp. 295–316.

Schiere H and van der Hoek R (2001) *Livestock Keeping in Urban Areas: A Review of Traditional Technologies Based on Literature and Field Experiences.* Issue 151. Rome, Italy: Food & Agriculture Organization of the UN (FAO).

Shochat E, Warren PS, Faeth SH, McIntyre NE and Hope D (2006) From patterns to emerging processes in mechanistic urban ecology. *Trends in Ecology & Evolution* 21, 186–191.

Silva F, Monobe MM, Lopes RS and Araujo JP (2012) Molecular characterization of *Giardia duodenalis* in dogs from Brazil. *Parasitology Research* 110, 325–334. Available at http://link.springer.com/10.1007/s00436-011-2492-3 (Accessed 27 September 2016).

Silva S, Richtzenhain LJ, Barros IN, Gomes AMMC, Silva AV, Kozerski ND, de Araújo Ceranto JB, Keid LB and Soares RM (2013) A new set of primers directed to 18S rRNA gene for molecular identification of *Cryptosporidium* spp. and their performance in the detection and differentiation of oocysts shed by synanthropic rodents. *Experimental Parasitology* 135, 551–557.

Taylor LH, Latham SM and Woolhouse MEJ (2000) Risk factors for human disease emergence. *Philosophical Transactions of the Royal Society B: Biological Sciences* 356, 983–989. Available at http://dx.doi.org/10.1098/rstb.2001.0888.

van Veenhuizen R and Danso G (2007) *Profitability and sustainability of urban and peri-urban agriculture.* Italy Rome: Food & Agriculture Organization of the UN (FAO).

Wang A, Ruch-Gallie R, Scorza V, Lin P and Lappin MR (2012) Prevalence of Giardia and Cryptosporidium species in dog park attending dogs compared to non-dog park attending dogs in one region of Colorado. *Veterinary Parasitology* 184, 335–340.

WHO (2017) Zoonoses. Available at http://www.who.int/zoonoses/diseases/en/ (Accessed 30 May 2017).

Zewdneh T, Ekwal I, Tsegabirhan K, Yohannes T and Kidane W (2013) Prevalence of gastrointestinal parasites and *Cryptosporidium* species in extensively managed pigs in Mekelle and urban areas of southern zone of Tigray region, northern Ethiopia. *Veterinary World* 6, 433–439.