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Zoonotic pathogens associated with pet and feeder murid rodent species: A global systematic review

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Running tittle: Zoonotic pathogens of pet and feeder rodents

Keywords: Infectious diseases, pet trade, rats and mice, surveillance, regulations, global assessment

Abstract

Pet and feeder rodents are one of the main sources of emerging infectious diseases. These rodents are purchased from pet shops, breeders, and through online. Consequently, some of these rodents may subtly transmit diseases as they may be asymptomatic for certain pathogens. We systematically searched four academic databases *viz.* Google Scholar, PubMed, Web of Science, and Scopus to determine zoonotic pathogens associated with pet and feeder rodents globally. Our searches were performed in R statistical software using the packages "*metagear*" and "*revtool*". We found 62 studies reporting on zoonotic pathogens between 1973 and 2022 from 16 countries representing four continents, namely Africa, Europe, Asia and North America. The review identified 30 zoonotic pathogens isolated from pet and feeder rodents, including the African pygmy mouse (*Mus minutoides*), brown rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*). The greatest number of pathogens were reported from the USA, followed by Togo and the UK. Bacterial pathogens were the most prevalent. However, the Seoul virus (SEOV) and rat bite fever (*Salmonella moniliformis*) were the most studied pathogens, found in more than one country, with reported outbreak cases. Most of the zoonotic pathogens were isolated from rodents acquired from pet shops. Therefore, we recommend that pet and feeder rodents purchased from pet shops should be regularly screened for potential zoonotic pathogens. There is also a critical need to develop strict regulations and policies, especially in underdeveloped and developing regions for an effective surveillance process, which will include early detection, rapid response, and control of zoonotic diseases globally. More research should be conducted in understudied regions, especially in underdeveloped and developing countries as they are likely to import or export feeder rodents and pet reptiles with zoonotic pathogens due to some animals not showing clinical signs of the illness.

Introduction

Several live non-native animal species have been introduced globally for purposes such as viewing in zoos, game farming, ornamentation, biomedical research, biological control, and for the exotic pet trade (Pimentel et al, 2000; Baker et al, 2013; Bush et al, 2014; Moshobane et al, 2020). The exotic pet trade has become a multibillion-dollar global business, with the reptile pet trade industry's annual revenue estimated at ~US$1.4 billion in the USA alone (Collis and Fenili, 2011; Gippet and Bertelsmeier, 2021). The number of households that keep exotic animals as companions or pets has also increased over the years (Warwick et al, 2018; Lockwood et al, 2019). It has been reported that most households in countries such as the USA, UK, and Germany keep one or two exotic animals as pets (Drews 2001; Pees et al, 2013; Kieswetter, 2017). These pets range from reptiles, amphibians, invertebrates, birds, and mammals (Bush et al, 2014; Gippet and Bertelsmeier, 2021). In recent years, an increase in the number of exotic animals has been reported for rodents, birds, and reptiles (Sterneberg-Van der Maaten et al, 2016). The increased demand for some species seems to be influenced by their popularity, cost, fashion advertisements, and celebrity interest (Harrington and D'Cruze, 2019).

Most celebrities own exotic pets, and this has led to a high demand for similar pets owned by celebrities (Harrington and D'Cruze, 2019; Hänninen, 2021). For example, most people in the USA became interested in kinkajous (*Potos flavus*) after its appearance with a well-known actress Paris Hilton in 2007, which has led to the increased popularity of this species in the country (Harrington and D'Cruze, 2019). Keeping exotic pets comes with a lot of responsibilities, as most of these animals require exceptional care, proper housing, expensive medication, and diet (Grant et al, 2017; Harrington and D'Cruze, 2019). Unfortunately, some of these species are abandoned at animal shelters or in the wild when they become aggressive to handle or expensive to care for (Reaser and Meyers, 2007; Stringham and Lockwood, 2018). Another reason for abandoning exotic pets is the fear of zoonotic diseases (Reaser and Meyers, 2007; Holmberg et al, 2015). Zoonotic diseases are illnesses or infections transmitted between animals and humans (Naicker, 2011; Ferreira et al, 2021). These infections are caused by disease-causing agents such as bacteria, parasites, fungi, and viruses (Weiss, 2008; Rahman et al, 2020).

Exotic pets are associated with various infectious diseases, including cat scratch fever caused by *Bartonella henselae*, monkeypox, and salmonellosis (Halsby et al, 2014; Rahman et al, 2020). It has been reported that exotic pets are one of the primary sources of emerging

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infectious diseases (Chomel et al, 2007; Smith and Whitfield, 2012; Bezerra-Santos et al, 2021). Diseases caused by pet animals can be fatal if not treated (Shvartsblat et al, 2004). Exotic pets such as birds, amphibians, reptiles, and small mammals have been linked to outbreaks of zoonotic diseases caused by *Salmonella*, Hantaviruses, the Seoul virus, and lymphocytic choriomeningitis virus in the USA (Centre for Disease Control and Prevention, 2022; Verela et al, 2022). Most zoonotic diseases caused by pets are transferred through petting, bites, scratches, and contact with an infected pet's excreta and/or saliva (Hönlinger et al, 2005; Gaastra et al, 2009; Damborg et al, 2016). In addition, pet food, including raw food diets, pet treats, frozen or live rodents (e.g., house mice (*Mus musculus*), brown rats (*Rattus norvegicus*)) and amphibians (e.g., the Chinese edible frog (*Hoplobatrachus rugulosus*)) used as feeders for predator pets such as reptiles and amphibians have been cited as possible sources of zoonotic diseases (Prapasarakul et al, 2012; Smith and Whitfield, 2012; Swanink et al, 2018; Vrbova et al, 2018; Varela et al, 2022).

To mitigate the potential impacts of exotic pet zoonoses on the public, interventions by stakeholders such as veterinaries, public health institutions and practitioners, the pet trade industry, researchers, and policy-makers are necessary (Smith and Whitfield, 2012). The discussions among these stakeholders should include thorough monitoring of the pet trade industry, modifying existing pet trade regulations, and educating the general public about the potential health risks associated with exotic pets. Moorhouse et al. (2016) reported that information about zoonotic disease risks associated with exotic pets could reduce consumer demand by up to ~40%. Assessing potential zoonotic pathogens associated with exotic pets and pet products such as feeder animals and pet treats is critical. This may allow insights into pathogen/host associations and possibly the identification of either potential or future outbreaks, and develop appropriate regulations and policies around surveillance processes for early detection, rapid response, and control of zoonotic diseases globally, especially in underdeveloped and developing regions of the world.

The present review aimed to assess zoonotic pathogens associated with pet and feeder murid rodents through a comprehensive systematic global literature assessment. The review also aimed at determining if the associated pathogens are bacterial, parasitic, fungal, or viral, and their associated rodent species. In addition, the review aimed to identify possible research gaps that may require further investigation on zoonotic pathogens related to pet and feeder rodents.

Methods

Literature search

We employed multiple literature searching regimes to gather information on global zoonotic diseases associated with pet and feeder rodent species. The relevant peer-reviewed published literature was searched via the following academic databases: 1) Web of Science (https://www.webofscience.com/wos/); 2) Scopus (https://www.scopus.com); 3) PubMed (https://pubmed.ncbi.nlm.nih.gov/advanced); 4) and Google Scholar (https://scholar.google.com/). For the published literature on Web of Science, PubMed, and Scopus, we used a Boolean search by inserting the search terms or phrases combined with AND/OR in the website Query boxes (Supplementary Fig. S1). The following keywords or phrases were used: "*pet*", "*feeder*", "*rodent*", "*rat*", "*mouse*", "*mice*", "*outbreak*", "*zoonotic disease*", "*zoonosis*", and "*zoonotic pathogens*" (Supplementary Fig. S1). For Google Scholar, we searched using the terms "*pet rodent outbreaks*", "*pet rodent zoonotic diseases*", "*pet rat and mice/mouse outbreak*", "*pet rat and mice zoonotic diseases*", "*pet rodent zoonosis*", "*pet rodent zoonotic pathogens*", "*feeder rodent zoonotic diseases*", "*feeder rodent outbreak*", "*feeder rat and mice/mouse outbreak*", "*feeder rat and mice zoonotic diseases*", "*feeder rodent zoonosis*", and "*feeder rodent zoonotic pathogens*".

The search results were selected according to the peer-reviewed publication's relevance and exported as RIS, BIB and NBIB files readable in R statistical software (version 4.1.3, R Core Team, 2022). The searches were undertaken in English; however, we found one study (Mignard et al, 2007) published in French, with an English abstract. Therefore, we were able to incorporate that study since it included useful information in its abstract and, we were able to translate this study to English. In addition, our information was restricted to zoonotic pathogens of pet and feeder rodents. The R statistical software (version 4.1.3, R Core Team, 2022) was used to draw a flowchart showing how a Boolean search was conducted and how the peer-reviewed publications were either selected or excluded in Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al, 2009).

Literature screening

The exported data were screened in R statistical software version 4.1.3 using the packages "*metagear*" and "*revtool*" (Lajeunesse, 2016; Westage 2019; R Core Team, 2022). We combined all the literature from the academic databases mentioned above into a single file and assessed relevant literature by selecting all the studies which mentioned our keywords in their abstract and title (Supplementary Fig. S1). Duplicated papers were excluded prior to analysing the abstracts related to our searches. We read all the abstracts and full articles to identify whether they met our selection criteria (Fig. 1, Supplementary Fig. S1). For each study, we extracted and analysed the following information: i) zoonotic disease associated with feeder and/or pet rodents; ii) rodent species associated with the zoonotic disease; iii) type of zoonotic pathogen (i.e., whether bacterial, parasitic, fungal, or viral); iv) source of trade or pet origin (e.g., pet shop, breeder, or pet owner); v) year of publication; and vi) countries where the study was conducted (Supplementary Fig. S1). We used ArcGIS version 10.6 (ESRI, 2022) to map the geographical regions where these studies were conducted.

Results

Number of identified studies

We found a total of 62 papers from 1973 to 2022 reporting on zoonotic pathogens associated with pet or feeder rodents across 16 countries (Fig. 2, Supplementary Fig. S2; Supplementary references). The majority of the studies were conducted in the 20th century than in the 19th century (Fig. 2). The research on zoonotic pathogens associated with pet and feeder rodents was first published in the USA and Norway in 1973 and 1992, respectively (Supplementary Table S1). There was a steady increase in the number of publications from 2004 onwards and a decrease from 2009 to 2010. The greatest number of publications were in the last five years, particularly in 2017 and 2018, with seven and six studies, respectively (Fig. 2). These studies were conducted in at least seven countries that included the USA, UK, France, Japan, Belgium, Canada, and the Netherlands (Supplementary Table S1). Europe and North America were well-represented in terms of research throughout the study years, with the UK and Canada being the latest countries to continue with research in 2021 and 2022 (Supplementary Table S1). We found that Asia and Africa were the least represented countries, with Asia having three studies in 2012, 2017 and 2020, while Africa only had one study in 2021 conducted in Togo (Supplementary Table S1).

Geographical locations

Two studies were conducted in more than one country, i.e., one study shared between Canada and the USA (Kerins et al, 2018), and another conducted in Belgium and France (Mori et al, 2017), therefore making the total number of studies conducted per country to be 64. A large proportion of studies were conducted in North America, followed by Europe. The USA

(20/64 (i.e., 31.3% of the studies)) had the greatest number of studies, followed by the UK (9/64; 14.1%), France (7/64; 11%), and Germany (7/64; 11%) (Fig. 3; Supplementary Fig. S2). No studies were identified in two continents, i.e., Australia and South America (Fig. 3). Our literature search found a total of 30 zoonotic pathogens of pet and/or feeder rodents across the four continents (Fig. 3). North America had the greatest number of zoonotic pathogens reported, followed by Europe (Fig. 3). The USA was the most frequently represented country, with 13 zoonotic pathogens reported, followed by Togo (number of zoonotic pathogens; $n = 8$), the UK ($n = 5$), and France ($n = 5$) (Fig. 3).

Nine zoonotic pathogens were reported in more than one country, i.e., Seoul virus (UK, Sweden, Netherlands, France, and USA); *Hymenolepis nana* (Japan, Italy, Mexico, Slovakia, and USA); *Leptospira interrogans* (Denmark, Germany, France, Belgium, and UK); *Streptobacillus moniliformis* (Canada, USA, France, and Norway); *Salmonella typhimurium* (Canada and USA); *S. enterica* (USA and Thailand); *S. enteritidis* (Canada and UK); *L. borgpetersenii* (Belgium and France); *Escherichia coli* (USA and Togo); and Cowpox virus (Germany and France) (Fig. 3). Twenty-two papers covered individual case reports or outbreaks involving more than 10 cases associated with contact with infected rodents or reptiles obtained from breeding facilities and pet shops (Supplementary Table S1). The cases were associated with the following pathogens *Cowpox virus* (5 papers), *Leptospira* spp (4 papers), *Salmonella enterica* (2 papers), *S. enteritidis* (1 paper), *S. typhimurium* (4 papers), *Seoul hantavirus* (2 papers), and *Streptobacillus moniliformis* (7 papers) (Supplementary Table S1).

The cases involved the following countries Canada, Denmark, France, Germany, the Netherlands, Norway, the UK, and the USA (Supplementary Table S1). Consequently, the outbreak of some cases resulted from the import and export of pet or feeder rodents between the countries (Supplementary Table S1). For example, the Seoul virus in the USA and Canada, and Cowpox infection in France was due to pet rats that a pet dealer imported from a breeder in the Czech Republic (Ducournau et al, 2013; Kerins et al, 2018). For most cases, rodents were asymptomatic, and the transmission was through direct contact with an infected rodents (Supplementary Table S1).

Zoonotic pathogens

Pet rodents accounted for 71% (44 papers) of the studies on zoonotic pathogens, while feeder rodents accounted for 26% (16 papers), and both pet rodents and feeder rodents accounted for only 3% (2 papers) (Fig. 4). Bacterial pathogens were frequently reported, followed by parasitic and viral pathogens. For bacterial pathogens, 18 pathogens were identified, with five identified to species level and *S. moniliforms* being the most studied pathogen (Fig. 4). However, in terms of bacterial prevalence, species from the genus *Leptospira* and *Salmonella* were the most prevalent. Seven species of parasitic pathogens were identified, with *H. nana* identified in six out of 14 studies. For viral zoonotic pathogens, four species were identified, with the Seoul virus identified in 13 out of 23 studies. This species was identified in both pet and feeder rodents, making it the most studied and published zoonotic pathogen. We only identified one fungal pathogen study isolated from pet rodents, i.e., *Microsporum* spp. (Fig. 4).

Rodent species and sources of trade/origin

We identified three rodent species which are commonly traded as both pets and feeders for carnivorous pets, i.e., the African pygmy mouse (*Mus minutoides*), the house mouse (*Mus musculus*), and the brown rat (*Rattus norvegicus*) (Table 1). Rats accounted for 64% (47 studies) of papers on zoonotic pathogens, while mice accounted for 36% (27 studies) (Table 1). However, in terms of zoonotic prevalence, mice were associated with a total of 20 pathogens, while 17 pathogens were isolated from rats. Overall, pet shops were the primary source from where rodents were obtained. Some of the zoonotic pathogens were identified from rats and mice obtained from breeding facilities/breeders, pet owners, and veterinary clinics (Table 1). The most prevalent zoonotic pathogen, the Seoul virus was identified from *R. norvegicus* obtained from three different sources, i.e., pet owners, pet shops, and breeding facilities/breeders (Table 1).

Discussion

Number of studies identified

Our global systematic review on zoonotic pathogens of pet or feeder rodents showed a marked increase in the number of publications in the 20th century. This increase may be explained by the international recognition of the zoonotic disease threats posed by exotic pets and the wildlife trade (Chomel et al, 2007; Pavlin et al, 2009). In addition, the number of households that keep pet rodents has increased over the years, particularly in the USA where ownership has been reported to have increased by 11% between 2007 and 2012 (Sterneberg-Van der Maaten et al, 2016; Lankau et al, 2017). Consequently, the increased ownership of these pets poses health risks to humans. For example, the number of human salmonellosis cases in the USA has been reported to have increased in parallel with the ownership of pet iguanas (Chomel et al, 2007). Notably, our review indicated an increase in the number of publications on zoonotic pathogens and human infections from 2007 to 2008 in the USA. Most of the studies followed outbreak incidents, for example, a study in Canada followed an outbreak of human *Salmonella enteritidis* illness associated with exposure to pet mice in 2018 and 2019 (Plotogea et al, 2022).

Areas of geographical focus

Although pet rodents and reptiles are kept as pets and traded globally, research on their potential health risks to humans is lacking in most exporting countries (Lankau et al, 2017; Valdez, 2021). This indicates an existing research gap in investigations focusing on zoonoses of pet and/or feeder rodents. For example, two continents (Australia and South America) had no studies on zoonotic pathogens of pet/feeder rodents, while Asia and Africa had less than four studies. The lack of research in these continents may be explained by the lack of funding or priorities in research focus areas. Another explanation could be that none of these continents have experienced an outbreak as a result of keeping exotic pet reptiles and rodents. However, the lack of research focussing on pet and feeder species is of great concern as these continents export reptiles and some rodent species to other continents (Valdez, 2021; https://trendeconomy.com/data/commodity_h2/010620). For example, the outbreak of monkeypox in the USA in 2003 was associated with the domestic trade of species such as Gambian giant rats (*Cricetomys gambianus*), dormice (*Glis* spp.), and striped mice (*Rhabdomys* spp.) that are indigenous to Africa (Centre for Disease Control and Prevention, 2003; Bernard and Anderson, 2006).

Another possible explanation for high number of publications in Europe and North America could be that these continents have experienced outbreaks related to the increased keeping of exotic pets such as rodents and reptiles. For example, the outbreak of *Salmonella* in the USA and the UK, Seoul virus (USA), Cowpox virus (Germany and Canada), and Lymphocytic choriomeningitis virus (USA) between 2008 and 2020 (Centre for Disease Control and Prevention, 2005; Fuller et al, 2008; Lee et al, 2008; Harker et al, 2011; Vogel et al, 2012; Edison et al, 2014; Cartwright et al, 2016; Kanagarajah et al, 2018; Kerins et al, 2018; Vrbova et al, 2018; Knust et al, 2020; Plotogea et al, 2022). Although we could only find one study in Africa (Togo) (D'Cruze et al, 2020), the country had the second-greatest number of zoonotic pathogens identified. This indicates that Togo is a high-risk country in terms of its potential to export reptile species with zoonotic pathogens, including asymptomatic individuals (D'Cruze et al, 2020).

Zoonotic pathogens

Both pet and feeder rodents were found to have been the source of zoonotic pathogens responsible for outbreaks in several countries. Zoonotic pathogens such as *S. moniliformis*, *Salmonella* spp., and *Leptospira* spp. are difficult to detect as some rodent pets or feeder rodents may not show the symptoms of the illness. Consequently, diseases such as Rat-bite fever, Salmonellosis, and leptospirosis may be transferred to humans through contact or bite by an infected pet rat, and or carnivorous pets, such as snakes and lizards (Campe et al, 2009; Mori et al, 2017). The lack of clinical symptoms in these pets may increase the chances of transmission from pets to humans and possible outbreaks. For example, the outbreak of the Seoul virus in 2017 was linked to pet rats exports and imports between Canada and the USA (Kerins et al, 2018). This suggests that countries should screen rodents and other exotic pets before importation and exportation to prevent possible outbreaks and transmissions. In addition, breeding facilities and pet shops should screen the animals before selling them to customers.

Rodent species and sources of trade/origin

Our literature search found that *M. musculus* and *R. norvegicus* are frequently studied in research focussing on zoonotic pathogens. We, therefore, suggest that more studies focussing on potential health risks associated with other pet and feeder rodent species should be conducted. For example, the southern multimammate mouse (*Mastomys coucha*) is traded as a pet and feeder rodent (Shivambu et al, 2022); however, there is little information on its potential zoonotic risks in the pet trade industry. In addition, some of the studies in our review did not indicate their study species but rather their generic common names, such as rats and mice. Consequently, such studies make it difficult to trace which species may be of concern. Of particular interest, zoonotic pathogens isolated from feeder mice in a study by D'Cruze et al. (2020) in Togo were not found in other countries, suggesting that other rodent species may be involved and not just *M. musculus* and *R. norvegicus*.

Most zoonotic pathogens identified in the present review were associated with pets or feeders purchased from pet shops. It has been suggested that pet shops can play a vital role in controlling the spread of zoonotic infections as they are one of the primary sources where the public can acquire information on the risks associated with pets (Halsby et al, 2014). An asymptotic pet or feeder rodent can potentially transmit the illness to other pets within the shop, workers, and customers. It has been suggested that breeders are more reliable in getting healthy pets than some pet shops (Centre for Disease Control and Prevention, 2005; Patterson, 2006). This is because some pet shops take no responsibility for their pets, and most of their animals, especially rodents, are bred behind the pet shops and are mostly unhealthy due to inhumane treatment (Patterson, 2006).

Conclusions

Our systematic review found that studies on zoonotic pathogens of pet and feeder rodents are lacking in several counties, although they seem to import and export rodents to other countries. For example, we did not find any study from the Czech Republic, although the rodents responsible for cowpox infections in France were purchased from that country (Ducournau et al, 2013). This indicates the need to conduct more research on pets and feeder species, given the role played by these animals in transmitting diseases to humans. Both pet and feeder rodents pose health risks to humans. We, therefore, suggest that animals from pet shops and breeding facilities should be screened for zoonotic diseases as they may not show clinical signs of some zoonotic diseases. Studies should also investigate zoonotic pathogens associated with other feeder animals, as it is evident that more studies focus on feeder rodents, although other species such as frogs (*Hoplobatrachus rugulosus*) are used (Prapasarakul et al, 2012).

Recommendations

Given the recent Covid 19 pandemic that has had a significant global impact, it is recommended that global rather than country-specific protocols on how to handle pets and feeder species in facilities that handle these animals be developed. It is also recommended that there is a critical need to develop strict regulations and policies, especially in undeveloped and developing regions for an effective surveillance process, which will include early detection, rapid response, and control of zoonotic diseases globally. In addition, there is a research gap in terms of the number of studies conducted globally. Underdeveloped and developing countries are underrepresented in terms of research, as a result, we recommend that these countries conduct more research on zoonotic pathogens given that they are likely to export infected pet or feeder rodents and reptiles to other countries. A study by Varela et al. (2022) highlights some important recommendations on how to reduce the risk of transmission from feeder, and pet rodents. These recommendation should be used when developing global protocols on handling pet and feeder rodents.

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Authorship confirmation

Ndivhuwo Shivambu: Conceptualization, Methodology, Data analysis, Writing- Original draft preparation, Funding acquisition. **Tinyiko C Shivambu:** Conceptualization, Methodology, Data analysis, Reviewing, and Editing. **Christian T Chimimba:** Supervision, Conceptualization, Funding acquisition, Reviewing, and Editing.

Author Disclosure Statement

The authors declare that they have no conflict of interest.

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Ethical Approval Statement

This study does not require an ethical approval because no human or animal subjects were directly involved in the study.

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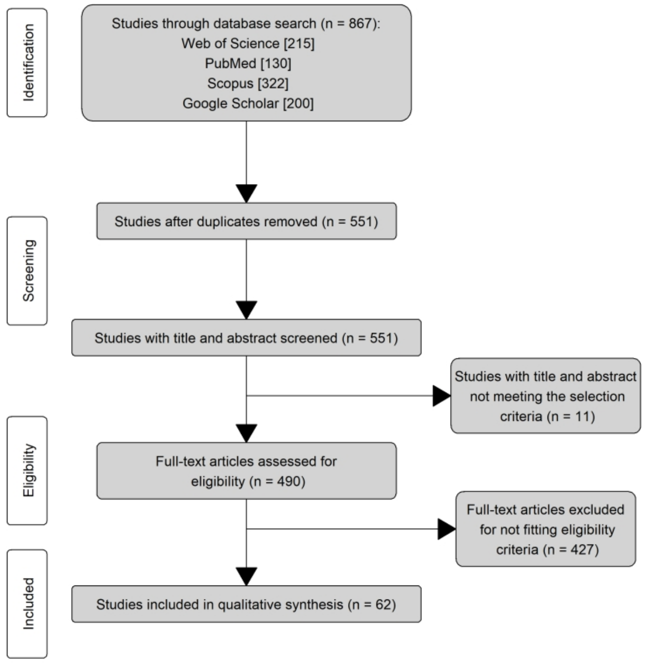
Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature review process for studies on zoonotic pathogens associated with pet or feeder rodent species globally.

Fig. 2. The number of publications per year associated with zoonotic pathogens of pet and/or feeder rodents across countries globally between 1973 and 2022.

Fig. 3. A map showing the geographic distribution of the number of studies on zoonotic pathogens associated with pet or feeder rodents between 1973 and 2022. LCV denotes Lymphocytic choriomeningitis virus. Countries abbreviations are as follows: BE – Belgium, NL- Netherlands, UK – United Kingdom, and USA – United States of America.

Fig. 4. Zoonotic pathogens associated with pet and/or feeder rodents identified in the literature globally.



Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature review process for studies on zoonotic pathogens associated with pet or feeder rodent species globally.

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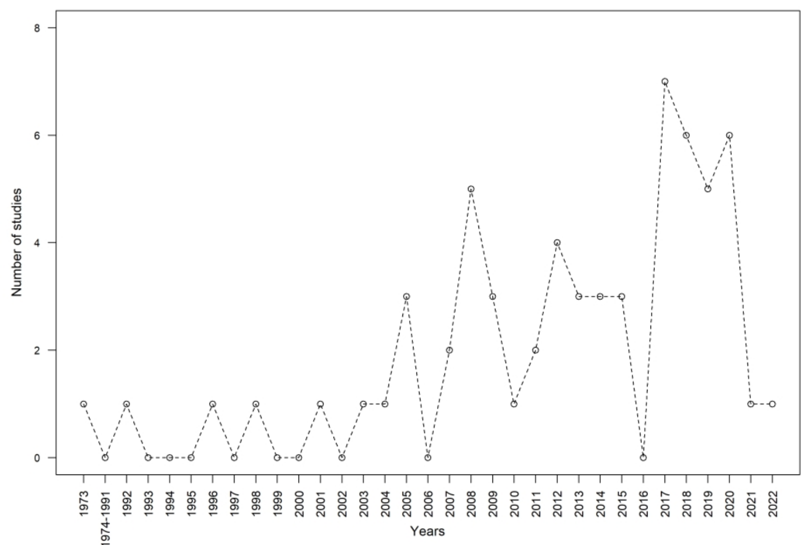

The number of publications per year associated with zoonotic pathogens of pet and/or feeder rodents across countries globally between 1973 and 2022.

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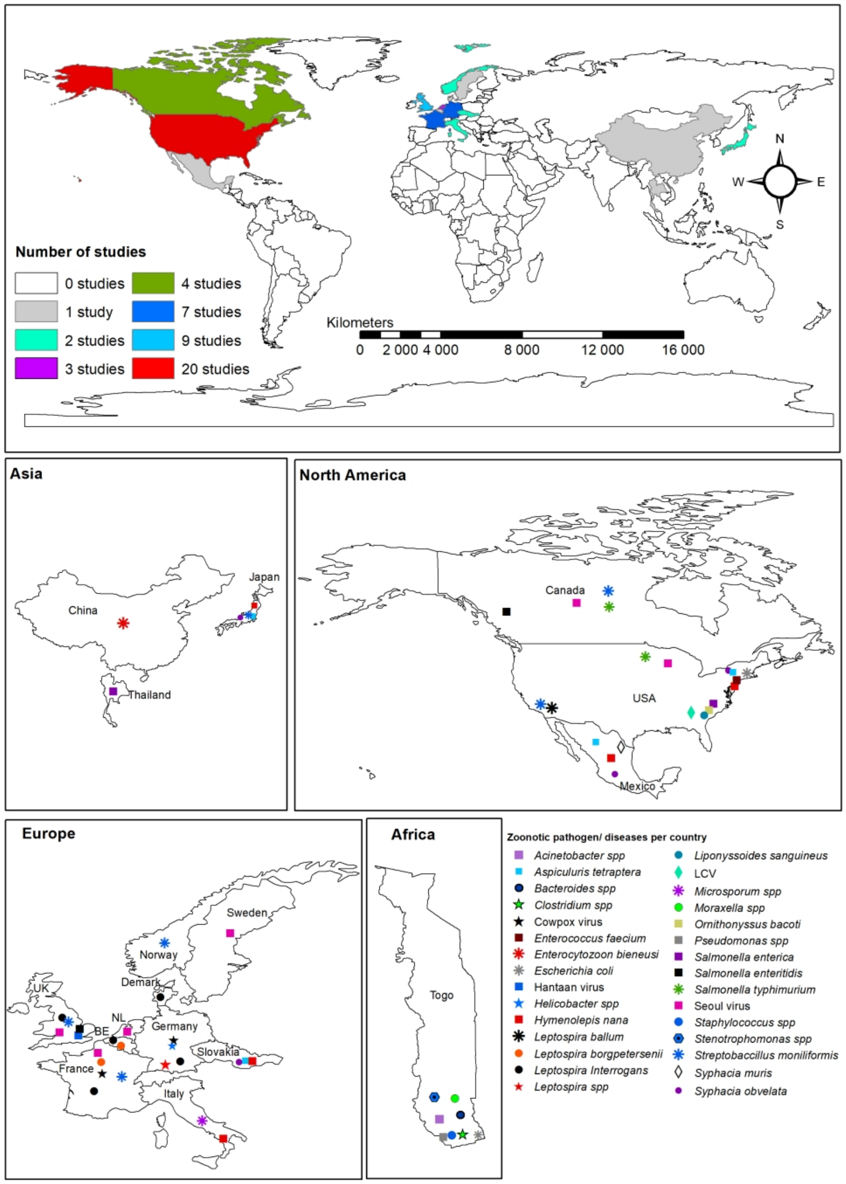

A map showing the geographic distribution of the number of studies on zoonotic pathogens associated with pet or feeder rodents between 1973 and 2022. LCV denotes Lymphocytic choriomeningitis virus. Countries abbreviations are as follows: BE – Belgium, NL- Netherlands, UK – United Kingdom, and USA – United States of America.

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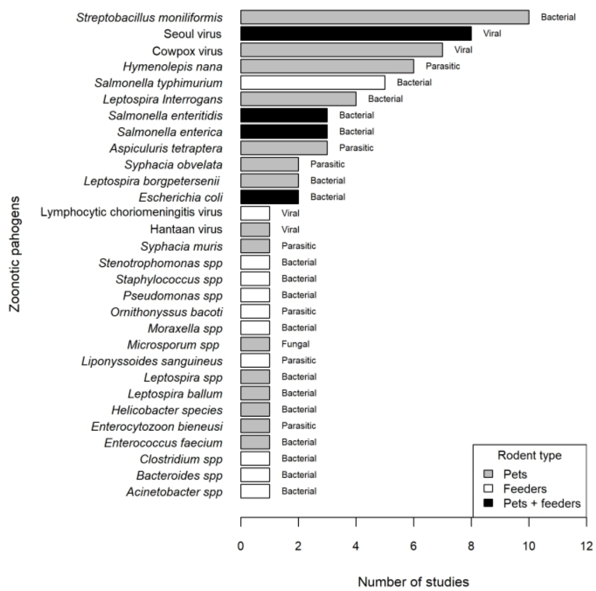

Zoonotic pathogens associated with pet and/or feeder rodents identified in the literature globally.

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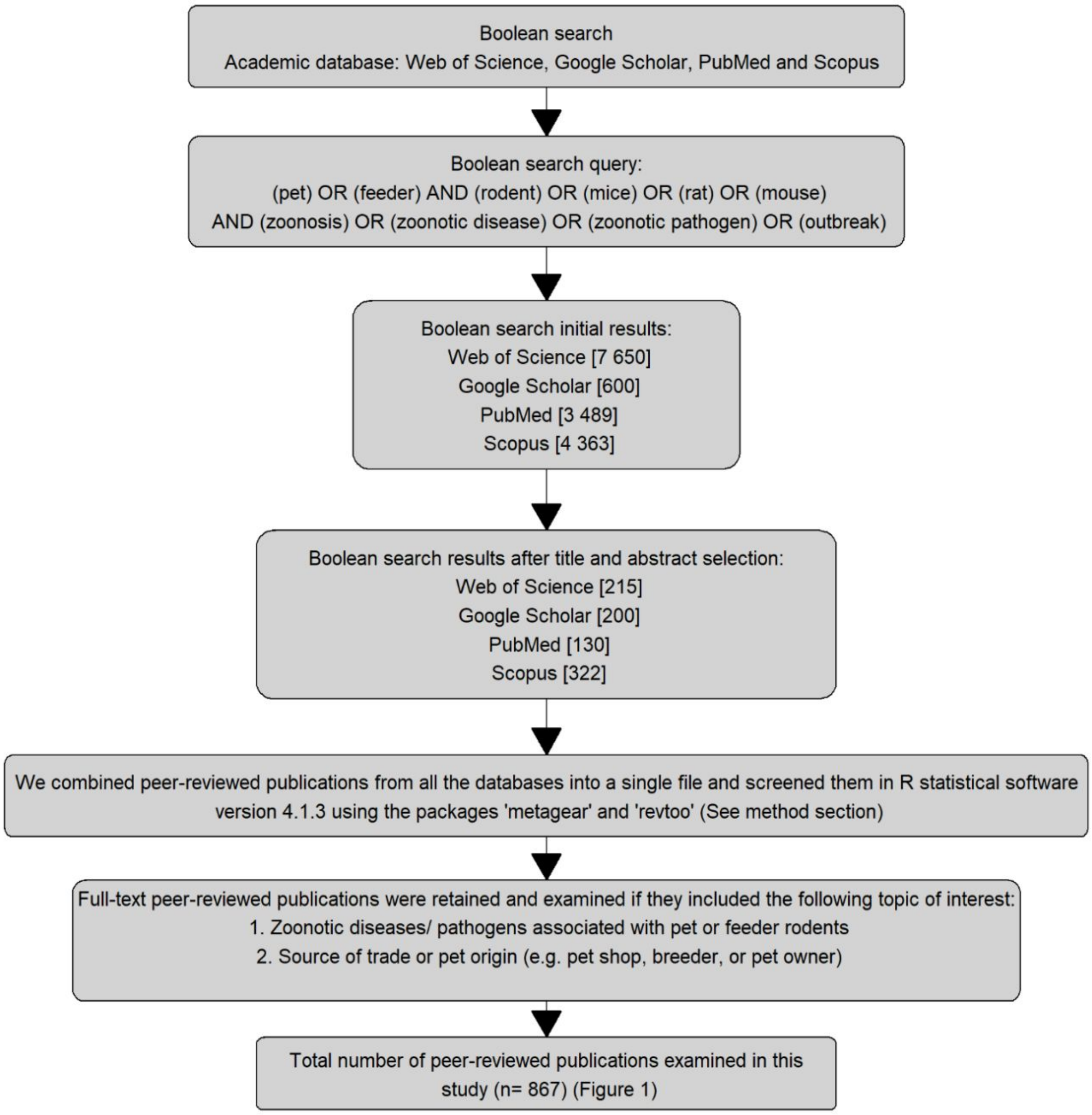
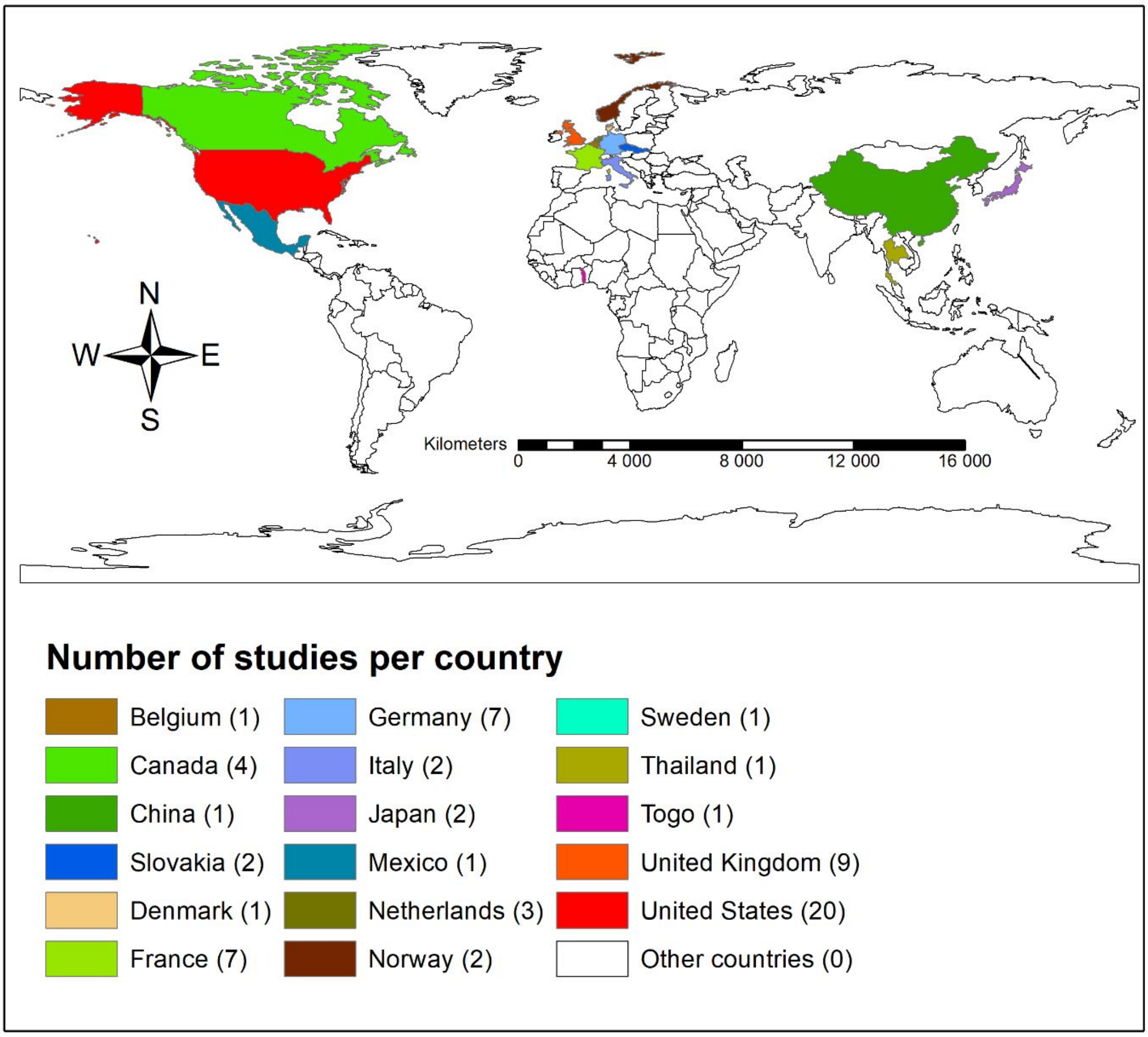
Table 1. Sources of pet and feeder rodents associated with zoonotic pathogens. The full references are provided in the Appendix B reference section.

Zoonotic pathogens	**Rodent host species**	**Animal source or pet origin**	**References**
Acinetobacter spp	Not specified	Breeding facility	21
Aspiculuris tetraptera	*Rattus norvegicus* and *Mus musculus*	Pet shop	30, 45, 55
Bacteroides spp.	Not specified	Breeding facility	20
Clostridium spp.	Not specified	Breeding facility	20
Cowpox virus	*R. norvegicus*	Pet shop	3, 4, 5, 17, 19, 43, 60
Enterococcus faecium	*M. musculus*	Pet shop	50
Enterocytozoon bieneusi	*R. norvegicus*	Pet shop	62
Escherichia coli	*R. norvegicus* and *M. musculus*	Pet owner	14, 20
Hantaan virus	*R. norvegicus*	Breeders/pet owners	18
Helicobacter species	*M. musculus*	Pet shop	13
Hymenolepis nana	*R. norvegicus*, *M. musculus* and *M. minutoides*	Pet shop	11, 12, 27, 29, 45, 50, 55
Leptospira ballum	*M. musculus*	Pet shop	22
Leptospira interrogans	*R. norvegicus*	Pet shop/pet owner	24, 25, 42,44
Leptospira spp.	*R. norvegicus*	Pet shop	51
Leptospira borgpetersenii	*R. norvegicus* and *M. musculus*	Pet shop	42
Liponyssoides sanguineus	*M. musculus*	Pet shop	48
Lymphocytic choriomeningitis virus	*R. norvegicus* and *M. musculus*	Breeding facility/pet shop	34
Microsporum spp.	*R. norvegicus*	Veterinary clinic	15
Moraxella spp.	Not specified	Breeding facility	20
Ornithonyssus bacoti	*M. musculus*	Pet shop	48
Pseudomonas spp.	Not specified	Breeding facility	20
Salmonella enterica	*R. norvegicus* and *M. musculus*	Breeding facility/pet shop	6, 47, 58
Salmonella enteritidis	*M. musculus*	Pet owner	31, 39, 46
Salmonella typhimurium	*R. norvegicus* and *M. musculus*	Pet owners/ pet shops/breeding facility	8, 23, 27, 35, 61

Zoonotic pathogens	Rodent host species	Animal source or pet origin	References
Seoul virus	*R. norvegicus*	Pet owners/ pet shops/breeding facility/ breeders	11, 21, 32, 31, 38, 49, 53, 57
Staphylococcus spp.	Not specified	Breeding facility	20
Stenotrophomonas spp.	Not specified	Breeding facility	20
Streptobacillus moniliformis	*R. norvegicus* and *M. musculus*	Pet shop/ pet owner	1, 2, 7, 10, 28, 36, 41, 52, 54, 56
Syphacia muris	*R. norvegicus* and *M. musculus*	Pet shop	45
Syphacia obvelata	*R. norvegicus* and *M. musculus*	Pet shop	30, 45, 55



Supplementary Fig S1. Boolean search flowchart showing how the systematic literature review was conducted.



Supplementary Fig S2. Number of studies per country indicating peer-reviewed publications on zoonotic pathogens associated with pet or feeder rodents.

Supplementary Table S1: Zoonotic pathogens associated with pet and feeder rodents identified through the global systematic literature review.

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
USA	Not specified	*Streptobaccillus moniliformis*	Bacteria	2014	Pet rats	Pet owner	A 10-year-old boy died after being admitted to the hospital. He experienced rigors, fevers, vomiting, headaches, and leg pains. During post-mortem lung, liver, and epiglottis tissue were collected. The tissues tested positive for *S. moniliformis* DNA by PCR. His rat was also tested and its oropharyngeal tissue was positive for *S. moniliformis*.	1
France	Not specified	*S.treptobaccillus moniliformis*	Bacteria	2005	Pet rats	Pet owner	A child owning pet rats developed an eruptive fever with blisters, polyarthritis, and spectacular desquamation of the hands. *Streptobacillus moniliformis* was identified by culture using a child's blister fluid, while *S moniliformis* from rat was detected by molecular methods using trachea biopsy samples.	2
Germany	Not specified	Cowpox virus	Virus	2019	Pet rats	Pet shop	Two specimens were collected from a 13-year old boy and his pet rat; the boy presented with local skin lesions and his rat died with severe pulmonary symptoms. The virus was detected using molecular analysis	3
Germany	*Rattus norvegicus*	Cowpox virus	Virus	2009	Pet rats	Pet shop	Cowpox virus was confirmed from 6 cases using molecular and serological findings. The cases had direct contact with pet rats.	4
Germany	*Rattus norvegicus*	Cowpox virus	Virus	2009	Pet rats	Pet shop	Five human cases of the cowpox virus were reported. The cases were a result of direct contact with pet rats purchased from a pet shop. Various specimens (skin biopsies, crusts, oral swabs, serum, and whole blood) obtained from 5 patients and from rats were homogenized and inspected for typical OPV-like particles using electron microscopy. The virus was isolated using molecular methods	5
USA	Not specified	*Salmonella enterica*	Bacteria	2015	Feeder mice and rats	Breeding facility	A total of 35 human samples were tested, however, the number of rats and mice tested was not specified. The bacteria were confirmed by CDC and FDA laboratories using serotyping and PFGE subtyping. Thirty-five cases were confirmed, with some cases confirming exposure to pet reptiles and frozen feeder rodents.	6
USA	Not specified	*Streptobaccillus moniliformis*	Bacteria	2003	Pet rats	Pet shop	Two cases of *S. moniliformis* were confirmed from a woman who had previous contact with pet fancy rats in the pet store and at home. Pet shop cases involved biting by a rat on the index finger, while the other case involves direct contact with an ill pet rat. The case's blood samples were used and bacteria were identified using a media culture. The 16S rRNA gene sequence was also used and DNA was extracted from paraffin-embedded, formalin-fixed samples of the liver and kidney.	7
USA	*Not specified*	*Salmonella typhimurium*	Bacteria	2005	Feeder mice and rats	Pet shop	In August 2004, a 5-year-old boy had diarrhoea of 14 days duration, abdominal cramps, vomiting, and fever. A stool culture yielded *S. typhimurium*. The boy had physical contact with a pet mouse purchased from a retail pet store. The mouse died one week after purchase. The cultures of the mouse's lungs, pooled liver and spleen, and intestines yielded growth of *S. typhimurium*, with a pulsed-field gel electrophoresis (PFGE) pattern indistinguishable from the boy's isolate.	8

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
USA	Not specified	*Salmonella enterica*	Bacteria	2012	Feeder mice	Breeding facility	A total of 46 cases were reported in 22 states in the USA from August 29, 2011 to February 2, 2012. The cases had exposure to rodents sold as food for pet reptiles and amphibians	9
USA	Not specified	*Streptobaccillus moniliformis*	Bacteria	1998	Pet rats	Pet owner	*Streptobacillus moniliformis* was detected in the patient's blood cultures. The patient reported being scratched by her pet rat.	10
Netherlands	*Rattus norvegicus*	Seoul virus	Virus	2018	Pet and Feeder rat	Private owners/ pet shops/shelters	Lung tissues of 175 pet and feeder rats collected from private owners, ratteries, and breeders tested using a SEOV real-time RT-qPCR were positive for SEOV: 1/29 rats from private owners (3.6%), 2/56 rats from ratteries (3.4%) and 11/90 rats from commercial breeders (12.2%).	11
Italy	*Mus minutoides* and *Rattus norvegicus*	*Hymenolepis nana*	Parasite	2015	Pet mice and rats	Pet shop	Fresh faecal samples were collected from 172 pet rodents as follows: guinea pigs (*Cavia porcellus*; *n* = 60), squirrels (*Callosciurus finlaysonii*, *C. prevosti*, *Tamias striatus*, *T. sibiricus*, *Sciurus calorinensis*; *n* = 52), hamsters (*Phodopus campbelli*, *Mesocricetus auratus*; *n* = 30), chinchillas (*Chinchilla lanigera*; *n* = 13), rats (*Rattus norvegicus*; *n* = 10), and mice (*Mus minutoides*; *n* = 7). All fecal samples were processed using the FLOTAC pellet technique to assess the number of eggs per gram (EPG) of feces. Eggs of *H. nana* were found in 24 out of 172 (13.9 %; 95% confidence interval = 9.3–20.2 %) pet rodents. Of those rodents, 41.6 % (10/24) were rats (mean EPG = 55.7; range = 2–200), 29.2 % (7/24) mice (mean EPG = 64.5; range = 32–120), 25.0 % (6/24) were chinchillas (mean EPG = 25.5; range = 10–50), and 4.2 % (1/24) hamsters (*P. campbelli)* (EPG = 86.0).	12
Germany	*Mus musculus*	*Helicobacter species*	Bacteria	2011	Pet mice	Pet shop	House mice sold as pets or feed specimens were purchased from different pet shops and tested for a comprehensive panel of unwanted microorganisms. The following microorganisms were found, *Helicobacter* species (92.9%), mouse parvovirus (89.3%), mouse hepatitis virus (82.7%), *Pasteurella pneumotropica* (71.4%,) and *Syphacia* species (57.1 %). For bacteriological and fungal analyses, tissue samples, swabs and intestinal content of each animal were identified by culture on blood samples.	13
Togo	Not specified	*Acinetobacter spp* *Bacteroides* *Clostridium* *Escherichia* *Moraxella spp* *Pseudomonas spp* *Staphylococcus spp* *Stenotrophomonas*	Bacteria	2020	Feeder rats	Farm	Five mice were tested for bacterial prevalence. The bacteria belonging to the genera *Clostridium*, *Escherichia,moraxella*, and *Stenotrophomonas* were confirmed from the oral and rectal samples taken from five mice used to feed ball pythons. Molecular analysis was used to detect the bacterial prevalence.	14
Italy	*Rattus norvegicus*	*Microsporum spp*	Fungi	2014	Pet rats	Vertarinary clinic	A total of 655 medical records of exotic pet mammals were examined between 2011 and 2012. Of these, only 11 records were rats. The fungal zoonotic agent, *Microsporum* spp, was isolated from only one rat sample.	15

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
UK	Not specified	*Streptobaccillus moniliformis*	Bacteria	2001	Pet rats	Pet shop	A 14-year-old boy was admitted to the hospital. A case of septic arthritis was reported. The boy had been bitten on a finger by the pet rat he bought from a pet shop. *Streptobaccillus moniliformis* was isolated from seropurulent material using special media culture.	16
France	*Rattus norvegicus*	Cowpox virus	Virus	2013	Pet rats	Pet shop	Four human cases of cowpox virus infection were reported in France in 2011. The patients had contact with imported pet rats. Cowpox virus was detected using molecular testing of the patient's ion samples using 14-kDa protein gene–targeting real-time PCR for Orthopoxvirus detection	17
UK	*Rattus norvegicus*	Hantaan virus Seoul hantavirus	Virus	2017	Pet rats	Breeder/private owner	A total of 844 individual blood samples were collected. Of these, 79 samples were from those who had exposure to pet rats. Hantavirus seroprevalence amongst the pet fancy rat owner group was 34.1% (95% CI 23·9–45·7%), and 2·4% (95% CI 0·6–5·9) for those with occupational exposure to pet fancy rats. Blood samples were processed and serum was analysed using a hantavirus-specific IFA.	18
France	Not specified	Cowpox virus	Virus	2011	Pet rats	Pet shop	The case was admitted with an acute inflammatory lesion of the left ear lobe. The swab samples of the left ear lobe were taken and the Cowpox virus was detected using molecular analysis based on PCR. The case reported physical contact with two pet rats purchased from a local pet shop. The rats became sick, with respiratory and haemorrhagic disorders, and died 2 and 6 days later.	19
USA	Not specified	*Escherichia coli*	Bacteria	2019	Pet mice and rats	Pet owner	A total of 65 animals, including mice, rats, rabbits, guinea pigs, and hedgehogs, were screened. Twenty-six *E. coli* isolates were obtained from 24 animals. Twelve of the 26 isolates (46.2%) were PCR-positive for the pks genes clbA and clbQ. Two isolates (7.7 %) were PCR-positive for cnf. Nine *E. coli* isolates were cultured from 36 guinea pigs (25%), Seven *E. coli* isolates were cultured from nine rats (77.8%), one *E. coli* isolate was cultured from 12 rabbits (8.3%), three *E. coli* isolates were cultured from four hamsters (75%), two E. coli isolates were cultured from two mice (100%), and two *E. coli* isolates were cultured from two hedgehogs (100%).	20
USA	Not specified	Seoul virus	Virus	2017	Pet rats	Pet owner	An outbreak of Seoul virus infection was identified among rat breeders and owners in Wisconsin and Illinois, USA in January 2017. The cases were related to exposure to pet rats. Rats owned by one patient were linked to the confirmed Seoul virus of infected pet rats. The virus was detected from blood specimens by immunoglobulin M and immunoglobulin G by enzyme-linked immunosorbent assay and reverse transcription PCR.	21
USA	Not specified	*Leptospira ballum*	Bacteria	1973	Pet mice	Pet shop	The investigation revealed the patient's pet mice as the source of *L. ballum*. It was detected from the case's blood at a dilution of 1:800. The pet mice were killed	22
USA	Not specified	*Salmonella typhimurium*	Bacteria	2008	Feeder mice and rats	Breeding facility	Out of 49 environmental swabs, seven were *Salmonella*-positive and out of 88 frozen feeder rodents, one adult mouse was *Salmonella*-positive. All samples were positive by culture. The pulsed-field gel electrophoresis (PFGE) subtype patterns of S. Typhimurium isolates from feeder rodent and environment samples were not separable from the outbreak strain isolated from humans. A follow-up investigation was conducted on other identified feeder rodent facilities in Texas, USA and out of 100	23

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
							rodent samples, seven were *Salmonella*-positive in one of the four facilities investigated.	
UK	Not specified	*Leptospira interrogans serogroup icterohaemorrhagiae*	Bacteria	2008	Pet rats	Pet shop	The case developed a 'flu-like' illness, which progressed to hepatorenal failure over a 48-hour period. The illness was confirmed serologically as Weil's disease using an in-house IgM ELISA (positive at 1:320) and the microscopic agglutination test (mat) for IgG and IgM (positive at 1:640). The agent was serogrouped as *L icterohaemorrhagiae*. The case is linked to close contact with pet rats. Blood taken from pet rats was strongly seropositive (1:400 and 1:1600) for *L icterohaemorrhagiae* by mat, and pathogenic leptospiral DNA was subsequently detected by PCR in kidney tissue from one rat.	24
Germany	*Rattus norvegicus*	*Leptospira Interrogans*	Bacteria	2008	Pet rats	Pet owner	Using a combination of bacteriological, serological, histological and molecular methods white fancy pet rats were identified as the potential infection source for acute leptospirosis in a human immunodeficiency virus (HIV)-positive patient.	25
UK	Not specified	*Salmonella typhimurium*	Bacteria	2010	Feeder mice	Internet/breeding facility	Human cases of *S. typhimurium* were associated with ownership or contact with reptiles, and frozen feeder mice. Phage-typing is an established method of detecting outbreaks of salmonellosis. All *S typhimurium* were isolated by Phage-typing method.	26
Japan	*Mus musculus*	*Aspiculuris tetraptera* *Hymenolepis nana* *Syphacia obvelata*	Parasite	2015	Pet mice	Pet shop	A total of 25 mice from 5 pet shops were investigated for 17 viruses, 22 bacteria and fungi, 10 parasites using culture tests, serology, PCR, and microscopy. Of interest, zoonotic pathogens isolated were *A. tetraptera*, *Syphacia obvelata* (8 mice each; 28.5%) and *Hymenolepis nana*, in 7 mice (25%).	27
Canada	Not specified	*Streptobaccillus moniliformis*	Bacteria	2019	Pet rats	Pet owner	A total of 11 cases of RBF were identified. *Streptobaccillus moniliformis* was identified by culture, and molecular analysis targeting the 16S RNA gene. Five cases had been bitten or scratched by pet rats.	28
Slovakia	*Mus musculus* and *Rattus norvegicus*	*Hymenolepis nana*	Parasite	2020	Pet mice and rats	Pet shop	Pooled faecal samples from 119 boxes with 228 mice, 191 rats, 124 hamsters and 25 Mongolian gerbils were collected from 12 pet shops and 3 breeding clubs. *Hymenolepis nana* eggs were detected in 25 (21.0%) boxes. Animals from pet shops were infected more frequently (24.6% positive boxes) than those from breeding clubs (17.2%), without statistical significance. The highest prevalence was recorded in rats from pet shops, where 41.7% of boxes contained parasite eggs. Hamsters and mice in pet shops were also frequently infected; in 23.8% and 25% of boxes, respectively, *H. nana* eggs were observed. Prevalence in rats and hamsters from breeding clubs was lower, but in mice surpassed 40%. Nine samples with positive PCR products in any of the four DNA regions, mitochondrial cox1 and nuclear pmy, ITS1 and ITS2 targets, gave profiles characteristic of *H. nana*.	29

Study area	**Species name**	**Zoonotic pathogen**	**Pathogen**	**Publication year**	**Host**	**Trade source**	**Study summary**	**References**
Slovakia	*Mus musculus* and *Rattus norvegicus*	*Aspiculuris tetraptera* *Syphacia muris* *Syphacia obvelata*	Parasite	2020	Pet mice and rats	Pet shop	Four species of oxyurid nematodes, *S. muris*, *S. obvelata*, *A. tetraptera,* and *P. uncinata* were detected. *Aspiculuris tetraptera* was found in the faecal samples of all rodent species included in this survey. The number of positive boxes varied from 5.4% in hamsters to 70.0% in mice. The prevalence of *S. muris* was highest in Mongolian gerbils where up to 75.0% boxes were positive; *S. obvelata* was found in 26.7% of boxes with mice, 25.0% of boxes with Mongolian gerbils and 3.2% of boxes with rats. The high prevalence of *Syphacia* spp. in all animal species points out the infection risk for humans.	30
UK	Not specified	*Salmonella enteritidis*	Bacteria	2018	Feeder mice	Pet shop	Exposure to pet reptiles and feeder mice were the risk factors. About 40% of the cases were aged less than 11 years old.	31
USA and Canada	*Rattus norvegicus*	Seoul virus	Virus	2018	Pet rats	Breeding facility	Human Seoul virus infections were confirmed by detection of Seoul virus-specific immunoglobulin M (IgM) and/or immunoglobulin G (IgG) antibodies by enzyme-linked immunosorbent assay (ELISA). Seoul virus infections in rats were confirmed through detection of viral RNA by reverse transcription–polymerase chain reaction (RT-PCR) and/or IgG ELISA at CDC, or by CDC-validated commercial IgG testing. In the USA, a total of 31 facilities in 11 states with human and/or rat Seoul virus infections reported exchanging rats with Canadian ratteries. The source of human infection was traced to a rattery and mode of transmission was contact.	32
USA	Not specified	Seoul virus	Virus	2020	Pet rats	Private owners	Direct contact with pet rats. A total of 17 people tested positive for SEOV IgM, with seven reporting symptoms and three hospitalized.	33
USA	*Mus musculus* and *Rattus norvegicus*	Lymphocytic choriomeningitis virus (LCMV)	Virus	2014	Feeder mice and rats	Pet shop	Direct contact with feeder mice. Of 97 employees tested, 31 (32%) tested positive for IgM and/or IgG to LCMV, and four employees were diagnosed with aseptic meningitis. Molecular analysis was used	34
USA	Not specified	*Salmonella typhimurium*	Bacteria	2008	Feeder mice and rats	Internet/breeding facility	A total of 21 human *S. typhimurium* isolates with indistinguishable PFGE patterns were identified in the USA. These cases had exposure to pet snakes and feeder rodents	35
Norway	Not specified	*Streptobaccillus moniliformis*	Bacteria	2020	Pet rats	Pet owner	Blood cultures of a previously healthy young woman were tested and came back positive for *S. moniliformis*. The case had contact with several pet rats and was scratched by one the rats that eventually died due to illness.	36
Sweden	Not specified	Seoul hantavirus	Virus	2013	Pet rats	Imported/breeder	During late spring, three rat owners initially brought their pet rats to be tested by the National Veterinary Institute (SVA), and among the three respective rats tested, one was found to be SEOV infected.	37

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
Netherlands	*Rattus norvegicus*	Seoul virus	Virus	2019	Feeder rats	Breeding facility	A total of 19 adult and 11 juvenile feeder rats were screened for SEOV using rRT-PCR and SEOV RNA. All adult rats were positive for SEOV specific antibodies and viral RNA in their tissues. One juvenile rat was seropositive. In addition, organs of the 19 adult rats were also positive, with SEOV RNA detected in all lungs, followed by kidney (79%) and liver (74%).	38
UK	Not specified	*Salmonella enteritidis*	Bacteria	2018	Feeder mice	Private owners	A total of 295 frozen feeder mice were tested (60 pinkies, 60 fuzzies, 60 small, 60 large, and 55 extra-large). At least 28.8% (*n* = 17) of the 59 batches tested, were *Salmonella enteritidis* PT8 and PT13-positive by media culture.	39
UK	*Rattus norvegicus*	Seoul hantavirus	Virus	2017	Pet rats	Breeder/private owner	A total of 24 rats were screened for hantavirus. Seoul hantavirus (SEOV) RNA was detected in the heart, kidney, lung, salivary gland and spleen of a rat suspected of being the source of SEOV.	40
France	Not specified	*Streptobaccillus moniliformis*	Bacteria	2007	Pet rats	Pet shop	Pet-rat bite fever is a relatively rare disease following a rat bite or scratch. The authors reported a case of septic arthritis following a pet rat bite. *Streptobacillus moniliformis* was identified in the knee synovial fluid and identified by 16S rRNA sequencing. This is a rapid and efficient tool for the identification of fastidious bacterium. The patient was cured by an amoxicillin treatment	41
Belgium and France	*Not specified*	*Leptospira borgpetersenii Serogroup Sejroe* *Leptospira Interrogans* *Leptospira borgpetersenii sg Ballum*	Bacteria	2017	Pet mice and rats	Pet shop	Six human cases of leptospirosis were associated with direct contact with pet mice or rats. *Leptospir*a spp. was identified in the DNA of the kidneys of owners' pet animals, suggesting that the excretion of leptospirosis in urine was the mode of transmission.	42
France	*Rattus norvegicus*	Cowpox virus	Virus	2009	Pet rats	Pet shop	Four human cases of cowpox virus were reported in northern France. The cases were as a result of direct contact with infected pet rats. Biopsy samples were used for molecular diagnosis using PCR targeting the cowpox hemagglutinin gene.	43
Denmark	Not specified	*Leptospira Interrogans*	Bacteria	2019	Pet mice	Pet owner	Upon admission to the hospital, the case presented a 1-week history of fever, headache, myalgia, vomiting, diarrhoea, and dark urine. *Leptospira interrogans* serovar sejroe was detected using microagglutination test. The patient a direct contact with pet mice, and one of the mice had fallen ill with conjunctivitis 1.5 months prior to the onset of the patient's symptoms.	44
Mexico	*Mus musculus* and *Rattus norvegicus*	*Aspiculuris tetraptera* *Hymenolepis nana/ Rodentolepis nana*	Parasite	2017	Pet mice and rats	Pet shop	A total 98 rodents were purchased from six pet shops and one black market: 46 mice, 28 hamsters (*Mesocricetus auratus*), 23 rats and one gerbil (*Meriones unguiculatus*). The overall prevalence of helminths in rodents was 61.2% (60/98). Six species of helminths were identified: *Rodentolepis nana* found in two mice, *Syphacia obvelata* in 36 mice, *Syphacia muris* in four rats and *Aspiculuris tetraptera* in 28 mice.	45

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
		Syphacia muris						
		Syphacia obvelata						
Canada	Not specified	*Salmonella enteritidis*	Bacteria	2022	Feeder mice	Pet shop/breeding facility	Five individuals with *S. enteritidis* infections were identified in the province of British Columbia (BC), Canada. These infections are suspected to have occurred from contact with surfaces at the mice facility contaminated with the bacteria. Isolates were sent to the National Microbiology Laboratory (NML) for WGS which is conducted by extracting genomic DNA from pure culture using the EZ1 DNA tissue kit and EZ1.	46
Thailand	*Mus musculus*	*Salmonella enterica*	Bacteria	2012	Feeder mice	Breeding facility	Pulsed-field gel electrophoresis (PFGE) was used to analyse serovars common to both human beings and snakes or snake and feeds. The prevalence of *Salmonella* spp. was 100.0% in cobras, 91.6% in feeder frozen frogs, and 50.0% in mice. Three of the eight human samples were found positive for *Salmonella* spp	47
USA	*Mus musculus*	*Liponyssoides sanguineus*	Parasite	2005	Feeder mice	Pet shop	Fifteen frozen mice were purchased from 15 pet shops and examined for ectoparasites using a microscope. Two species of the zoonotic pathogen were identified, with *L sanguineus* found in one mouse and *O. bacoti* also found in one mouse.	48
		Ornithonyssus bacoti						
France	*Rattus norvegicus*	Seoul virus	Virus	2017	Pet rats	Pet owner	Seoul virus was detected in three patients. Hantavirus was also detected in 434 patients. Hantavirus IgM and IgG were detected in an admission serum sample by using commercial ELISAs. SEOV was detected using, molecular techniques. One of the patient's pet rat was considered the source of the virus. The animal was euthanized after the consent of the patient was obtained. An identical partial SEOV small RNA sequence was obtained from the liver of the animal.	49
USA	*Mus musculus*	*Enterococcus faecium*	Bacteria	2012	Pet mice	Pet shop	The survey investigated the prevalence of ectoparasites and endoparasites, including viral, bacterial, and fungal agents carried mice. A total of 18 pet mice from six pet shops were investigated, Three mice were positive for *E. faecium* by culture, while direct examination of intestines revealed *Syphacia obvelata* in seven mice, *Aspiculuris tetraptera* in one mouse and *R. nana* in nine mice.	50
		Aspiculuris tetraptera	Parasite					
		Hymenolepis nana/ Rodentolepis nana						
		Syphacia obvelata						
Germany	Not specified	*Leptospira spp*	Bacteria	2008	Pet rats	Pet shop	The patient fell ill with acute undifferentiated fever after being bitten by a pet rat. A serum sample was examined by a more sensitive MAT and an ELISA, and showed a significant increase for *L. interrogans* serovar. Leptospira DNA was also detected by a novel qPCR from the kidney of the biting pet rat.	51
Norway	Not specified	*Streptobaccillus moniliformis*	Bacteria	1992	Pet rats	Pet owner	*Streptobacillus moniliformis* was detected from the blood cultures of a 5-year old patient. The patient had been playing with her grandmother's pet rats, which had later died from an unknown disease.	52

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
UK	*Rattus norvegicus*	Seoul orthohantavirus	Virus	2021	Pet rats	Breeder	A woman tested positive for SEOV and direct contact with rats was the main transmission mode.	53
USA	Not specified	*Streptobaccillus moniliformis*	Bacteria	2004	Pet rats	Pet shop	A pet shop employee contracted the disease after a minor finger wound from a contaminated rat cage. The bacteria were identified using a blood culture.	54
USA	Not specified	*Hymenolepis nana* *Syphacia obvelata*	Parasite	1996	Pet mice	Pet shop	A total of 260 mice and 85 hamsters were examined. These rodents were purchased from pet shops, commercial suppliers, and university department stores. The total number of mice from commercial dealers and Syracuse University animal room infected with *H. nana* was 43, *S. obvelata* was 152, and *A. tetraptera* was 61. The total number of mice from pet shops, department stores, classrooms infected with *H. nana* was 58, *S. obvelata* was 31, and *A. tetraptera* was 36.	55
USA	Not specified	*Aspiculuris tetraptera*	Parasite	1996	Pet mice	Pet shop	A total of 260 mice and 85 hamsters were examined. These rodents were purchased from pet shops, commercial suppliers, and university department stores. The total number of mice from commercial dealers and Syracuse University animal room infected with *H. nana* was 43, *S. obvelata* was 152, and *A. tetraptera* was 61. The total number of mice from pet shops, department stores, classrooms, infected with *H. nana* was 58, *S. obvelata* was 31, and *A. tetraptera* was 36.	55
Japan	Not specified	*Streptobaccillus moniliformis*	Bacteria	2017	Pet rats	Pet shop	A pet shop employee who sustained a bite from one of the store's rats developed fever and arthritis. *Streptobacillus moniliformis* was detected from the employee's blood culture.	56
Netherlands	Not specified	Seoul virus	Virus	2018	Feeder rats	Breeding facility	An autochthonous human case of SEOV infection was detected in the Netherlands. This case was exposed to feeder rats and a feeder rat farm. The virus was identified using a hantavirus genus-specific real-time reverse transcription PCR (rRT-PCR) and antibodies in rat serum were detected by using a human SEOV ELISA.	57
USA	Not specified	*Salmonella enterica*	Bacteria	2007	Pet and Feeder rat	Pet shop/breeding facility	*Salmonella enterica* serotype Typhimurium was isolated from 28 patients in whom the onset of illness occurred between December 2003 and September 2004. A total of 22 patients were interviewed. Of these, 13 reported exposures to pet hamsters, mice, or rats, and two had secondary infections. The outbreak strain of *S. enterica* serotype Typhimurium was cultured from pet mice and hamsters purchased from pet stores.	58
UK	*Rattus norvegicus*	Seoul hantavirus	Virus	2013	Pet rats	Pet owner	Seoul hantavirus RNA was detected by RT-PCR1 in blood taken from two pet rats and from seven of the larger group.	59
Germany	Not specified	Cowpox virus	Virus	2012	Pet rats	Pet shop	Eight patients from the Munich area in Germany who had purchased infected pet rats from a local supplier were diagnosed with Cowpox virus infection. The virus was detected using PCR.	60
Canada	Not specified	*Salmonella typhimurium*	Bacteria	2018	Feeder mice and rats	Private owners/ pet shops/breeding facility	A total of 134 cases who had direct contact with feeder rodents and pet reptiles were identified.	61

Study area	Species name	Zoonotic pathogen	Pathogen	Publication year	Host	Trade source	Study summary	References
China	*Rattus norvegicus*	*Enterocytozoon bieneusi*	Parasite	2020	Pet rats	Pet shop	A total of 325 faecal samples were collected from 152 pet fancy rats and 173 pet guinea pigs purchased from pet shops in Henan and Shandong provinces in China. The prevalence of *E bieneusi* was 11.2% (17/152) in pet fancy rats and 20.2% (35/173) in pet guinea pigs. Genotypes D (*n* = 12), Peru11 (*n* = 3), S7 (*n* = 1) and SCC-2 (*n* = 1) were identified in pet fancy rats, and genotype S7 (*n* = 30) and a novel genotype PGP (*n* = 5) were identified in pet guinea pigs. *Enterocytozoon bieneus*i was examined by nested PCR targeting a ~390-bp fragment of the ITS region.	62

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