

Rodent-related zoonotic pathogens at the human-animal-environmental interface in Qatar: a systematic review and meta-analysis

Supplementary Table S2: List of rodent-borne zoonotic diseases

1 Bacterial diseases

#	Disease	Causal agent	Rodent role	References
1	Bartonellosis	<i>Bartonella</i> spp. such as <i>B. doshiae</i> , <i>B. elizabethae</i> , <i>B. grahamii</i> , <i>B. rochalimae</i> , <i>B. tribocorum</i> , <i>B. vinsonii</i> subsp. <i>Arupensis</i> , and <i>B. washoensis</i>	Reservoir	[1-5]
2	Campylobacteriosis	<i>Campylobacter</i> spp., such as <i>C. coli</i> , <i>C. fetus</i> , <i>C. hyointestinalis</i> , and <i>C. jejuni</i>	Carrier	[2,3,6-9]
3	Corynebacteriosis /Non-diphtheritic <i>Corynebacterium</i>	<i>Corynebacterium</i> spp.	Reservoir	[3,6]
4	<i>E. coli</i> enteritis	<i>Escherichia coli</i> 0157/VTEC	Carrier	[2,3,9]
5	Ehrlichiosis	<i>Ehrlichia</i> spp. such as <i>E. chaffeensis</i> , <i>E. equi</i> , <i>E. ewingii</i> , <i>E. morulae</i> , <i>E. muris</i> , <i>E. phagocytophilum</i> , <i>E. risticii</i> , and <i>E. sennetsu</i>	Reservoir	[1,10-12]
6	Leptospirosis	<i>Leptospira interrogans</i>	Carrier	[1-3]
7	Listeriosis	<i>Listeria</i> spp. such as <i>L. monocytogenes</i> and <i>L. ivanovii</i>	Carrier	[2,3,13]
8	Lyme disease	<i>Borrelia burgdorferi</i>	Reservoir	[1-3]
9	Pasteurellosis	<i>Pasteurella</i> spp.	Reservoir	[3,14]
10	Plague	<i>Yersinia pestis</i>	Carrier	[1-3]
11	Rickettsial Pox	<i>Rickettsia akari</i>	Reservoir	[1-3]
12	Q-Fever	<i>Coxiella burnetii</i>	Carrier	[2,3]
13	Rat-bite fever	<i>Spirillum minus</i> and <i>S. moniliformis</i>	Carrier	[2,3]
14	Relapsing fever (Tick-borne/Lice borne)	<i>Borrelia</i> spp. such as <i>B. duttoni</i> , <i>B. hermsii</i> , <i>B. parkeri</i> , <i>B. recurrentis</i> , and <i>B. turicatae</i>	Reservoir	[1-3,15]
15	Salmonellosis	<i>Salmonella</i> spp. such as <i>S. enterica</i> and <i>S. enteritidis</i>	Reservoir	[2,3,6,9]
16	Japanese spotted fever	<i>Rickettsia japonica</i>	Reservoir	[1]
17	Mediterranean spotted fever /Boutonneuse	<i>Rickettsia conorii</i>	Reservoir	[3]
	Queensland spotted fever/ tick typhus	<i>Rickettsia australis</i>	Reservoir	[2]
18	Rocky mountain spotted fever	<i>Rickettsia rickettsi</i>	Reservoir	[1-3]
19	Tuberculosis	<i>Mycobacterium microti</i> , a member of <i>Mycobacterium tuberculosis</i> complex	Reservoir	[3,16-18]
20	Tularemia	<i>Francisella tularensis</i>	Carrier	[1-3]
21	Murine typhus /Endemic typhus	<i>Rickettsia typhi</i>	Reservoir	[1-3]
22	Scrub Typhus	<i>Orientia tsutsugamushi</i>	Reservoir	[1,2]
23	Siberian Typhus	<i>Rickettsia sibirica</i>	Reservoir	[1]
24	Sylvatic Typhus /Epidemic thymus	<i>Rickettsia prowazekii</i>	Reservoir	[1-3]

25	Yersiniosis	<i>Yersinia pseudotuberculosis</i> , <i>Y. enterocolitis</i>	Reservoir	[1,3]
----	-------------	--	-----------	-------

2 Fungal diseases

#	Disease	Causal agent	Rodent role	References
1	Dermatophytosis	Dermatophytes fungus	Carrier	[1]
2	Histoplasmosis	<i>Histoplasma capsulatum</i>	Reservoir	[1,19]
3	Penicilliosis	<i>Penicillium marneffe</i>	Reservoir	[1,20]

3 Parasitic diseases

#	Disease	Causal agent (Type, name)	Rodent role	References
1	Moniliformiasis	Acanthocephala, <i>Moniliformis moniliformis</i>		[3]
2	Echinococcosis	Cestode, <i>Echinococcus</i> spp., such as <i>E. granulosus</i> , <i>E. multilocularis</i> , <i>E. oligarthrus</i> , and <i>E. vogeli</i>	Reservoir	[1-3,21,22]
3	Hymenolepiasis	Cestode, <i>Hymenolepis diminuta</i> , <i>H. nana</i> , and <i>H. microstoma</i>	Reservoir	[1-3,23]
4	Taeniasis	Cestode, <i>Taenia</i> spp., such as <i>T. brauni</i> , <i>T. crassiceps</i> , <i>T. glomeratus</i> , <i>T. hydatigena</i> , <i>T. martis</i> , <i>T. pisiformis</i> , <i>T. serialis</i> , <i>T. taeniaeformis</i> , <i>Versteria mustelae</i>	Reservoir	[2,3,24,25]
5	Aelurostrongylosis	Nematode, <i>Aelurostrongylus abstrusus</i>	Reservoir	[2]
6	Angiostrongyliasis	Nematode, <i>Angiostrongylus cantonensis</i>	Reservoir	[1-3]
7	Baylisascariasis	Nematode, <i>Baylisascaris procyonis</i>	Reservoir	[1-3]
8	Capillariasis	Nematode, <i>Capilaria hepatica</i>	Reservoir	[1-3]
9	Gongylonemiasis	Nematode, <i>Gongylonema pulchrum</i>		[3,26]
10	Toxascariasis	Nematode, <i>Toxascaris leonina</i>	Reservoir	[2,3]
11	Trichinellosis	Nematode, <i>Trichinella</i> spp., such as <i>Trichinella spiralis</i>	Reservoir	[2,3,27]
12	Trichuriasis	Nematode, <i>Trichuris</i> spp.		[3]
13	Alariasis	Trematode, <i>Alaria</i> spp., such as <i>A. alata</i> and <i>A. Americana</i>	Reservoir	[2,3,28,29]
14	Brachylaimiasis	Trematode, <i>Brachylaima cribbi</i>	Reservoir	[2,3]
15	Echinostomiasis	Trematode, <i>Echinostoma</i> spp. such as <i>E. echinatum</i> , <i>E. japonicus</i> , <i>E. perfoliatus</i> , <i>E. cinetorchis</i> , <i>E. Hortense</i> , <i>E. ilocanum</i> , <i>E. revolutum</i> , <i>Isthmiophora melis</i>	Reservoir	[1-3,30-32]
16	Fascioliasis	Trematode, <i>Fasciola hepatica</i> , <i>F. gigantica</i>	Reservoir	[1-3]
17	Plagiorchiasis	Trematode, <i>Plagiorchis muris</i> , <i>P. hilippinensis</i> , <i>P. javanensis</i>		[3]
18	Schistosomiasis	Trematode, <i>Schistosoma mansoni</i>	Reservoir	[1-3]
19	Amoebic dysentery	Protozoa, <i>Entamoeba histolytica</i>	Reservoir	[2]
20	Anaplasmosis/ Human granulocytic anaplasmosis	Protozoa, <i>Anaplasma phagocytophilum</i>	Reservoir	[1-3]
21	Babesiosis	Protozoa, <i>Babesia</i> spp. such as <i>Babesia microti</i>	Reservoir	[2,3,33]
22	Cryptosporidiasis	Protozoa, <i>Cryptosporidium</i> spp. (<i>Cryptosporidium parvum</i> , <i>Cryptosporidium hominis</i> , <i>Cryptosporidium meleagridis</i> , <i>Cryptosporidium muris</i>)	Reservoir	[1-3,34,35]

23	Giardiasis	Protozoa, <i>Giardia lamblia</i>	Reservoir	[1-3]
24	Leishmaniasis (cutaneous, mucocutaneous, and visceral)	Protozoa, <i>Leishmania braziliensis</i> , <i>L. donovani</i> , <i>L. infantum</i> , <i>L. major</i> , and <i>L. tropica</i>	Reservoir	[1-3]
25	Neosporosis	Protozoa, <i>Neospora caninum</i>	Reservoir	[2,3]
26	Toxoplasmosis	Protozoa, <i>Toxoplasma gondii</i>	Reservoir	[1-3]
27	Trypanosomiasis	Protozoa, <i>Trypanosoma brucei</i> and <i>T. cruzi</i>	Reservoir	[1-3]

4 Virus

#	Disease	Causal agent	Rodent role	References
1	Argentine/Junin/Mapucho hemorrhagic fever	<i>South American arenavirus</i> , Arenaviridae	Reservoir	[1-3,36]
2	Bolivian hemorrhagic fever	<i>Machupo virus</i> , Arenaviridae	Reservoir	[1,3,36]
3	Hemorrhagic fever Brazilian	<i>Sabia virus</i> , Arenaviridae	Reservoir	[3,36]
4	Lujo Hemorrhagic fever	<i>Lujovirus</i> , Arenaviridae	Reservoir	[3,36]
5	Venezuelan hemorrhagic fever	<i>Guanarito virus</i> , Arenaviridae	Reservoir	[1,3,36]
6	Lassa fever	Lassa virus (LASV), Arenaviridae	Reservoir	[1-3,36]
7	Lymphocytic choriomeningitis	Lymphocytic choriomeningitis (LCMV), Arenaviridae	Reservoir	[1-3,36]
8	North American arenavirus infection	<i>North American arenavirus</i> , Arenaviridae	Reservoir	[2,36]
9	Whitewater Arroyo virus infection	Whitewater Arroyo virus (WWAV), Arenaviridae	Reservoir	[1,36]
10	Borna disease	<i>Borna virus</i> , Bornaviridae	Reservoir	[2,3]
11	Hantavirus pulmonary syndrome	<i>Hantavirus</i> , Hantaviridae	Carrier	[1-3]
12	Hemorrhagic fever with renal syndrome	<i>Hantavirus</i> , Hantaviridae	Carrier	[2,3]
13	Nephropathia epidemica	<i>Hantavirus</i> , Hantaviridae	Carrier	[2]
14	Ebola	<i>Ebola virus</i> , Filoviridae	Reservoir?	[1]
15	Apoi virus disease	<i>Apoi virus</i> , Flaviviridae	Unknown	[2,3]
16	Tick-borne encephalitis	<i>TBE virus</i> , Flaviviridae	Reservoir	[1-3]
17	Omsk hemorrhagic fever	<i>OHF virus</i> , Flaviviridae	Reservoir	[2,3]
18	Kyasanur forest disease	<i>Kyasanur forest virus</i> , Flaviviridae	Reservoir	[2,3]
19	Powassan encephalitis	<i>Powassan virus</i> , Flaviviridae	Reservoir	[1-3]
20	West Nile fever	<i>West Nile virus</i> , Flaviviridae	Reservoir	[1]
21	Hepatitis E	<i>Orthohepevirus A</i> , Hepeviridae	Reservoir	[1-3]
22	Crimean-Congo hemorrhagic fever	<i>CCHF virus</i> , Nairoviridae	Reservoir	[1-3]
23	Encephalitis California	<i>California Encephalitis virus</i> , Peribunyaviridae	Carrier	[1]
24	Rift Valley fever	<i>Phlebovirus</i> , Phenuiviridae	Carrier	[1,3]
25	Cow Pox	<i>Cowpox/Vacciniavirus</i> , Poxviridae	Reservoir	[1-3]
26	Monkey Pox	<i>Monkeypox virus</i> , Poxviridae	Reservoir	[1,37]
27	Colorado tick fever	<i>Caltivirus</i> , Reoviridae	Reservoir	[1-3]

28	Rabies	<i>Rabies virus</i> , Rhabdoviridae	Reservoir	[1,3,38]
29	Chikungunya	<i>Chikungunya virus</i> , Togaviridae	Reservoir	[1,39]
30	Eastern Equine Encephalitis	<i>EEE virus</i> , Togaviridae	Reservoir	[1]
31	Venezuelan Equine Encephalitis	<i>VEE virus</i> , Togaviridae	Reservoir	[1-3]
32	Western Equine Encephalitis	<i>WEE virus</i> , Togaviridae	Reservoir	[2,3]
33	Mayaro	<i>Mayaravirus</i> , Togaviridae	Reservoir	[1]

5 References

- Han, B.A.; Schmidt, J.P.; Bowden, S.E.; Drake, J.M. Rodent reservoirs of future zoonotic diseases. *Proceedings of the National Academy of Sciences* **2015**, *112*, 7039, doi:10.1073/pnas.1501598112.
- Meerburg, B.G.; Singleton, G.R.; Kijlstra, A. Rodent-borne diseases and their risks for public health. *Crit Rev Microbiol* **2009**, *35*, 221-270, doi:10.1080/10408410902989837.
- Rabiee, M.H.; Mahmoudi, A.; Siahsharvie, R.; Kryštufek, B.; Mostafavi, E. Rodent-borne diseases and their public health importance in Iran. *PLoS Negl Trop Dis* **2018**, *12*, e0006256, doi:10.1371/journal.pntd.0006256.
- Favacho, A.R.d.M.; Andrade, M.N.; de Oliveira, R.C.; Bonvicino, C.R.; D'Andrea, P.S.; de Lemos, E.R.S. Zoonotic Bartonella species in wild rodents in the state of Mato Grosso do Sul, Brazil. *Microbes and Infection* **2015**, *17*, 889-892, doi:<https://doi.org/10.1016/j.micinf.2015.08.014>.
- Gonçalves, L.R.; Favacho, A.R.d.M.; Roque, A.L.R.; Mendes, N.S.; Fidelis Junior, O.L.; Benevenuto, J.L.; Herrera, H.M.; Andrea, P.S.; de Lemos, E.R.S.; Machado, R.Z., et al. Association of *Bartonella* species with Wild and Synanthropic Rodents in Different Brazilian Biomes. *Applied and Environmental Microbiology* **2016**, *82*, 7154, doi:10.1128/AEM.02447-16.
- Meerburg, B.G.; Kijlstra, A. Role of rodents in transmission of Salmonella and Campylobacter. *Journal of the Science of Food and Agriculture* **2007**, *87*, 2774-2781, doi:10.1002/jsfa.3004.
- Meerburg, B.G.; Jacobs-Reitsma, W.F.; Wagenaar, J.A.; Kijlstra, A. Presence of Salmonella and Campylobacter spp. in wild small mammals on organic farms. *Applied and environmental microbiology* **2006**, *72*, 960-962, doi:10.1128/AEM.72.1.960-962.2006.
- Edmonds, P.; Patton, C.M.; Griffin, P.M.; Barrett, T.J.; Schmid, G.P.; Baker, C.N.; Lambert, M.A.; Brenner, D.J. Campylobacter hyointestinalis associated with human gastrointestinal disease in the United States. *J Clin Microbiol* **1987**, *25*, 685-691.
- Nkogwe, C.; Raletobana, J.; Stewart-Johnson, A.; Suepaul, S.; Adesiyun, A. Frequency of Detection of Escherichia coli, Salmonella spp., and Campylobacter spp. in the Faeces of Wild Rats (Rattus spp.) in Trinidad and Tobago. *Vet Med Int* **2011**, *2011*, 686923-686923, doi:10.4061/2011/686923.
- Thomas, R.J.; Dumler, J.S.; Carlyon, J.A. Current management of human granulocytic anaplasmosis, human monocytic ehrlichiosis and Ehrlichia ewingii ehrlichiosis. *Expert Rev Anti Infect Ther* **2009**, *7*, 709-722, doi:10.1586/eri.09.44.
- Kawahara, M.; Ito, T.; Suto, C.; Shibata, S.; Rikihisa, Y.; Hata, K.; Hirai, K. Comparison of *Ehrlichia muris* Strains Isolated from Wild Mice and Ticks and Serologic Survey of Humans and Animals with *E. muris* as Antigen. *J Clin Microbiol* **1999**, *37*, 1123, doi:10.1128/JCM.37.4.1123-1129.1999.
- Tominello, T.R.; Oliveira, E.R.A.; Hussain, S.S.; Elfert, A.; Wells, J.; Golden, B.; Ismail, N. Emerging Roles of Autophagy and Inflammasome in Ehrlichiosis. *Front Immunol* **2019**, *10*, 1011, doi:10.3389/fimmu.2019.01011.
- Wang, Y.; Lu, L.; Lan, R.; Salazar, J.K.; Liu, J.; Xu, J.; Ye, C. Isolation and characterization of Listeria species from rodents in natural environments in China. *Emerg Microbes Infect* **2017**, *6*, e44, doi:10.1038/emi.2017.28.

14. Scharmann, W.; Heller, A. Survival and transmissibility of *Pasteurella pneumotropica*. *Lab Anim* **2001**, *35*, 163-166, doi:10.1258/0023677011911543.
15. Dworkin, M.S.; Schwan, T.G.; Anderson, D.E., Jr.; Borchardt, S.M. Tick-borne relapsing fever. *Infect Dis Clin North Am* **2008**, *22*, 449-viii, doi:10.1016/j.idc.2008.03.006.
16. van Soolingen, D.; van der Zanden, A.G.; de Haas, P.E.; Noordhoek, G.T.; Kiers, A.; Foudraine, N.A.; Portaels, F.; Kolk, A.H.; Kremer, K.; van Embden, J.D. Diagnosis of *Mycobacterium microti* infections among humans by using novel genetic markers. *J Clin Microbiol* **1998**, *36*, 1840-1845, doi:10.1128/JCM.36.7.1840-1845.1998.
17. Behr, M.A.; Gagneux, S. 24 - The Rise and Fall of the *Mycobacterium tuberculosis* Complex. In *Genetics and Evolution of Infectious Disease*, Tibayrenc, M., Ed. Elsevier: London, 2011; <https://doi.org/10.1016/B978-0-12-384890-1.00024-8>pp. 651-667.
18. Moradi, E.; Mosavari, N.; Tebianian, M.; Tadayon, K.; Ghaderi, R.; Soleymani Babadi, K.; Mohammad Taheri, M.; Dashtipour, S.; Loni, R.; Moradi Garavand, M., et al. Pest rodents as the essential elements of *Mycobacterium bovis* controlling programs. *International Journal of Mycobacteriology* **2015**, *4*, 137, doi:<https://doi.org/10.1016/j.ijmyco.2014.09.007>.
19. Emmons, C.W.; Ashburn, L.L. Histoplasmosis in Wild Rats: Occurrence and Histopathology. *Public Health Reports (1896-1970)* **1948**, *63*, 1416-1422, doi:10.2307/4586744.
20. Cao, C.; Liang, L.; Wang, W.; Luo, H.; Huang, S.; Liu, D.; Xu, J.; Henk, D.A.; Fisher, M.C. Common reservoirs for *Penicillium marneffei* infection in humans and rodents, China. *Emerg Infect Dis* **2011**, *17*, 209-214, doi:10.3201/eid1702.100718.
21. da Silva, A.M. Human echinococcosis: a neglected disease. *Gastroenterol Res Pract* **2010**, *2010*, 583297, doi:10.1155/2010/583297.
22. Tappe, D.; Stich, A.; Frosch, M. Emergence of polycystic neotropical echinococcosis. *Emerg Infect Dis* **2008**, *14*, 292-297, doi:10.3201/eid1402.070742.
23. Macnish, M.G.; Ryan, U.M.; Behnke, J.M.; Thompson, R.C. Detection of the rodent tapeworm *Rodentolepis* (=Hymenolepis) microstoma in humans. A new zoonosis? *Int J Parasitol* **2003**, *33*, 1079-1085, doi:10.1016/s0020-7519(03)00137-1.
24. Deplazes, P.; Eichenberger, R.M.; Grimm, F. Wildlife-transmitted *Taenia* and *Versteria* cysticercosis and coenurosis in humans and other primates. *Int J Parasitol Parasites Wildl* **2019**, *9*, 342-358, doi:10.1016/j.ijppaw.2019.03.013.
25. Spickler, A.R. Taeniasis, Cysticercosis, and coenurosis. In *Date of Factsheet*, 2020.
26. da Costa Cordeiro, H.; de Vasconcelos Melo, F.T.; Giese, E.G.; Santos, J.N.D. *Gongylostrongylus* Parasites of Rodents: A Key to Species and New Data on *Gongylostrongylus neoplasticum*. *J Parasitol* **2018**, *104*, 51-59, doi:10.1645/17-3.
27. Pozio, E. World distribution of *Trichinella* spp. infections in animals and humans. *Vet Parasitol* **2007**, *149*, 3-21, doi:10.1016/j.vetpar.2007.07.002.
28. Möhl, K.; Grosse, K.; Hamedy, A.; Wüste, T.; Kabelitz, P.; Lückner, E. Biology of *Alaria* spp. and human exposition risk to *Alaria mesocercariae*-a review. *Parasitol Res* **2009**, *105*, 1-15, doi:10.1007/s00436-009-1444-7.
29. Wasiluk, A. *Alaria alata* infection - threatening yet rarely detected trematodiasis. *Journal of Laboratory Diagnostics* **2013**.
30. Hildebrand, J.; Adamczyk, M.; Laskowski, Z.; Zaleśny, G. Host-dependent morphology of *Isthmiophora melis* (Schrunk, 1788) Luhe, 1909 (Digenea, Echinostomatinae)--morphological variation vs. molecular stability. *Parasit Vectors* **2015**, *8*, 481-481, doi:10.1186/s13071-015-1095-8.
31. Toledo, R.; Esteban, J.G. An update on human echinostomiasis. *Trans R Soc Trop Med Hyg* **2016**, *110*, 37-45, doi:10.1093/trstmh/trv099.
32. Gillespie, S.H.; Pearson, R.D. Principles and practice of clinical parasitology. **2010**.
33. Bloch, E.M.; Kumar, S.; Krause, P.J. Persistence of *Babesia microti* Infection in Humans. *Pathogens* **2019**, *8*, 102, doi:10.3390/pathogens8030102.
34. García-Livia, K.; Martín-Alonso, A.; Foronda, P. Diversity of *Cryptosporidium* spp. in wild rodents from the Canary Islands, Spain. *Parasit Vectors* **2020**, *13*, 445, doi:10.1186/s13071-020-04330-9.
35. Lv, C.; Zhang, L.; Wang, R.; Jian, F.; Zhang, S.; Ning, C.; Wang, H.; Feng, C.; Wang, X.; Ren, X., et al. Cryptosporidium spp. in Wild, Laboratory, and Pet Rodents in China: Prevalence and Molecular Characterization. *Applied and Environmental Microbiology* **2009**, *75*, 7692, doi:10.1128/AEM.01386-09.

36. Gravinatti, M.L.; Barbosa, C.M.; Soares, R.M.; Gregori, F. Synanthropic rodents as virus reservoirs and transmitters. *Rev Soc Bras Med Trop* **2020**, *53*, e20190486, doi:10.1590/0037-8682-0486-2019.
37. Buller, R.M.L. 170 - Poxviruses. In *Infectious Diseases (Fourth Edition)*, Cohen, J., Powderly, W.G., Opal, S.M., Eds. Elsevier: 2017; <https://doi.org/10.1016/B978-0-7020-6285-8.00170-2pp>. 1452-1457.e1451.
38. Fitzpatrick, J.L.; Dyer, J.L.; Blanton, J.D.; Kuzmin, I.V.; Rupprecht, C.E. Rabies in rodents and lagomorphs in the United States, 1995-2010. *J Am Vet Med Assoc* **2014**, *245*, 333-337, doi:10.2460/javma.245.3.333.
39. Vourc'h, G.; Halos, L.; Desvars, A.; Boué, F.; Pascal, M.; Lecollinet, S.; Zientara, S.; Duval, T.; Nzonza, A.; Brémont, M. Chikungunya antibodies detected in non-human primates and rats in three Indian Ocean islands after the 2006 ChikV outbreak. *Vet Res* **2014**, *45*, 52-52, doi:10.1186/1297-9716-45-52.