PATTERNS OF ZOONOTIC DISEASES AND ASSOCIATED SOCIO-ECONOMIC FACTORS IN TANZANIA: A SCOPING REVIEW

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Zoonotic diseases (ZDs) are important contributors of infectious disease burden especially in developing nations. In Tanzania, several factors have been associated with the distribution of ZDs among different populations. This review aimed at describing such a pattern together with their associated socio-economic factors. The search for relevant articles was carried in PubMed/MedLine with additional hand searched articles through Google and Google-Scholar. We identified a total of 1,087 relevant articles, 27 of which met our inclusion criteria. Our findings showed that the prevalence of Brucellosis, Leptospirosis, Q Fever, Rift Valley Fever, Cysticercosis, Echinococcosis, Schistosomiasis, Toxoplasmosis, Fascioliasis and Cryptosporidiosis were 0.6 - 48.4%, 10 - 33.9%, 5 - 20.3%, 4.5 - 5.2%, 2.7 - 16.7%, 11.3%, 15.8 - 63.91%, 57.7%, 21% and 4.3% respectively, depending on geographical locations. On other hand, levels of education, occupation, residence and ethnicity were associated with increased risks of ZDs in Tanzania. This review reinforces the need for more resilient surveillance and monitoring systems that can offer quality data for evidence-based policing. Likewise, it underscores the neglected burdens of most ZDs in Tanzania.

Keywords: Zoonotic disease, human, Tanzania, epidemiology.

I. INTRODUCTION

Zoonotic diseases (ZDs) are infectious diseases which can be transmitted from human to animals and vice versa. ZDs comprise an important global health burden with over 2.5 billion cases and 2.7 million deaths every year.[1] However, the global distribution of ZDs is markedly disproportionate with higher burden of ZDs among developing countries than in developed countries, with 25% and 1% of infectious diseases respectively.[2] ZDs are also important as they account for around 60% of emerging and re-emerging diseases, which consequently leads to high economic loss for both livestock and health sectors.[3]

In recent years, attention to ZDs has been rising due to emergence of ZDs like COVID-19, Avian Influenza and Ebola. However, little attention is given to other ZDs which are also of high prevalence especially among under-privileged populations. High risks of zoonotic diseases, is in some areas close to wildlife ecosystem, activities such as hunting and grazing impose higher risk of transmission from animals to human. Apart from that poverty elevation, lack of education and poor services among livestock keepers increase risk of contact with zoonotic diseases.[4,5]

In Tanzania, although little is known about the burden of zoonotic diseases, these diseases are still common in poor people living close to animals especially poor livestock keepers. Neglected parasitic, bacterial and viral zoonotic diseases are among some of the most common infectious zoonotic diseases reported. Regard inadequacy and inaccuracy of data on the burden of the zoonotic diseases, it difficult to estimate the health impacts and socio- economic effects of these diseases.[6]

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Therefore, this review delineate the pattern of ZDs and their associated socio-economic factors in Tanzania, which is one of the important hotspot zones for ZDs, using a selective list of 14 ZDs in accordance to WHO's 2005 report on control of neglected diseases and Tanzania's One Health strategic plan 2015 - 2020.

II. METHODS

1. Study design

Literature review

2. Search Strategy and Data Collection/ Extraction

Between July and August 2020, we conducted a literature search on PubMed/Medline for zoonotic and social economic factors for relevant articles using the search terms (zoonotic diseases OR Rift valley fever", "Anthrax", "Trypanosomiasis", "Brucellosis", "Leishmaniasis", "Echinococcosis", "Cysticercosis", "Q-fever", "Plague", "Leptospirosis", "Schistosomiasis", "Fascioliasis" and "Cryptosporidiosis") AND (Tanzania) with Boolean Operators; combination of the zoonotic disease and socio economic factors in Tanzania. Additionally, manual searching of records and reference tracing was conducted through Google-Scholar.

3. Data Screening

Retrieved articles were screened for inclusion/exclusion criteria that included:

- Peer reviewed article published between 2009 and 2019.

- Full text articles, in English language.

- Reported data on epidemiology of the specific zoonotic diseases in Tanzania.

Articles which were classified as eligible for inclusion were retrieved in full text format.

4. Data management and analysis

For analysis, we used a narrative review approach as meta-analysis would be faulty due to limited data for most of the ZDs. Our data extraction form captured sample size, infection prevalence, risk factors, socioeconomic factors, disease, host/vector; country and year of study, year of publication were extracted from included eligible articles and compiled. Excel spreadsheet was used in data processing, whereas Zotero was used for sorting out sources of references.

III. RESULTS

Specific ZDs had following retrieved records: seven Brucellosis;[7–13] six reporting on Leptospirosis;[11,14–18] two reporting on Q fever;[16,19] two reporting on Cysticercosis/ Taeniasis;[20,21] two reporting on Rift Valley fever;[22,23] one reporting on Fascioliasis;[24] one reporting on Echinococcosis;[25] one reporting on Toxoplasmosis;[25] four reporting on Schistosomiasis;[25–28] one reporting on Cryptosporidiosis.[29] The results are presented in Figure 1 and their findings are presented in table 1 for the pattern of ZDs in Tanzania between 2009 and 2019, and table 2for the socio-economic factors associated with ZDs.

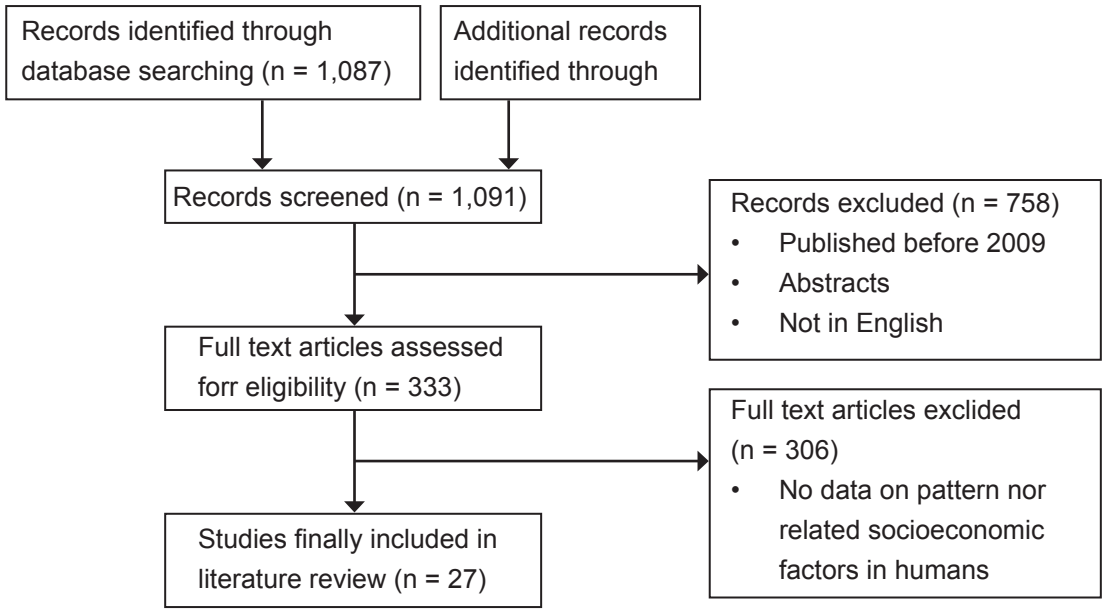

Figure 1. Flow diagram of search strategy

Table 1.Year of study, samples tested in humans and study outcomes of zoonosis in Tanzania between 2009 and 2019.

Year of publication	Number of Humans/samples tested(n)	Results/Seroprevalence (%,n)/ Incidence rate (case/100,000 population)				Ref
		Disease	Overall	Gender		
				Male(%, n)	Female (%, n)	
2009	High risk occupational groups (199)	Brucellosis	5.52 (95%CI: 2.79-9.77)	7.5 (95%CI3.69 - 13.4)	1.49 (95%CI 0.037 8.03)	8
2015	Febrile illness patient (370)	Brucellosis	7.0%	6.9%	16.0%	7
2019	Risk occupational (425)	Brucellosis	1.41 (95% CI: 0.01-0.03)	1.41 (95%CI 0.18-0.26)	0.00 (95%CI 0.74-0.82)	
2015	Agro-pastoralist (340)	Brucellosis	0.6 (95%CI 0.1-2.1)	****	****	10
2018	Abattoir workers (250)	Brucellosis	48.4% (95% CI: 42-54)	****	****	11
2017	Pastoralist communities (13642)	Brucellosis	5.8%	5.2%	6.4%	12
2012	South-western region (1228)	Rift Valley fever	5.2%	****	****	22
2018	Agro-Pastoral and Pastoral Communities (751)	Rift Valley fever	4.5% (95% C.I 3.2-6.3)	5.5%	3.9%	23
2016	Pastoralists community (267)	Leptospirosis	29.96%	****	****	18

Year of publication	Number of Humans/samples tested(n)	Results/Seroprevalence (%,n)/ Incidence rate (case/100,000 population)				Ref
		Disease	Overall	Gender		
				Male(%, n)	Female (%, n)	
2019	sugarcane plantation workers (455)	Leptospirosis	15.8%	****	****	15
2013	Febrile patients (870)	Leptospirosis	33.9%;	****	****	16
2009	Risk groups (199)	Leptospirosis	15.1% (95% CI. 10.4–20.8)	17.4 (95% CI.11.4–24.9)	10.4 (95% CI.4.3–20.3)	17
2018	Abattoir workers and meat vendor (250)	Leptospirosis	(10.0%, 95% CI:6±13)	****	****	11
2015	Katavi- Rukwa ecosystem (267)	Leptospirosis	29.96%	****	****	14
2013	Febrile patient (870)	Q fever	20.3%	****	****	16
2011	Febrile patients (215)	Q fever	5%	****	****	19
2013	Mbozi district (830)	Cysticercosis/ Taeniasis	16.7 (95% CI:14.2-19.2)	****	****	20
2019	Urban population (302)	Cysticercosis/ Taeniasis	2.7%	(0.7%; 95% CI: 0-1.6%)	****	21
2015	Patient (1460)	Fascioliasis	21%	34%	66%	24

Year of publication	Number of Humans/samples tested(n)	Results/Seroprevalence (%,n)/ Incidence rate (case/100,000 population)				Ref
		Disease	Overall	Gender		
				Male(%, n)	Female (%, n)	
2014	Northern region (345)	Echinococosis	11.3% (95% CI:7.96-14.6)	****	****	25
		Schistosomiasis	51.3% (95% CI:46.0-56.5)			
		Toxoplasmosis	57.68% (95% CI =52.5-62.9)			
2015	Gombe Ecosystem,	Cryptosporidium	4.3%; n = 8		****	29

**** Data not available

Table 2.Socio-economic factors associated with zoonotic disease

Factor	Association	Ref
Level of education	Primary education (OR: 2.64, 95% CI: 1.25–5.55, p = 0.011) increases risk of acquired Brucellosis	11
Occupation	Abattoir workers (n=41) (19.5%; 95%CI= 8.82- 20.3), Livestock farmers (n=67) (2.98%; 95%CI= 0.36 10.37).	8
	Sero-prevalence of Brucellosis for Shepherds 1.33% (95% CI: 0.14-0.22); Butcher men 5.26% (95% CI: 0.10-0.17) and abattoir workers 1.08% (95% CI: 0.39-0.49).	9
	Being abattoir workers(OR: 2.19, 95% CI 1.06–4.54, p = 0.035) and long working hours duration (OR: 1.06, 95%CI: 1.01±1.11, p = 0.014) increases risk of Brucellosis	11
	Prevalence of Leptospirosis among Agro-pastoralists were 29.96%	14
	Seroprevalence of RVFV pastoralists (8.9%, 20 of 227) and Agro-pastoralists (3.4%, 10 of 294)	23

Factor	Association	Ref
Residence	The Distance of house to nearest neighbour's house Continuous (OR: 0.98[95%CI=0.97-0.99; p=0.01] increases likelihood of Brucella infection	13
	Socioeconomic status (0.53(95% CI=0.34-0.84)), vegetation (PR 6.31, 95%CI 3.68-10.81) and cattle density (PR 2.06 per 100/skm, 95% CI 1.64 to 2.59) associated with higher prevalence ratio of RVFV	22
	Living near wildlife ecosystem (OR: 1.8, 95%CI=1.14-3.39) increase odds for RVFV.	23
Urbanization	Urban prevalence of T. Solium cysticercosis-Ag (0.99%; 95% CI: 0–2.11%, n=3), - Abs (2.65%; 95% CI: 0.84 –4.46%, n = 8), and taeniasis-Abs (1.66%; 95% CI: 0.22–3.09%, n = 5) among 302 people with epilepsy.	21
Ethnic groups	The seroprevalance for RVFV among pastoralists (8.9%, 20 of 227) and Agro-pastoralists communities (3.4%, 10 of 294) (p = 0.008). Odds of exposure among pastoral communities (aOR 2.9, 95% C.I: 1.21–6.89, p < 0.01)	23

IV. DISCUSSIONS

This review presents a comprehensive description of important ZDs in Tanzania. However, the prevalence of ZDs summarised in this review must be interpreted carefully, as many of the studies were conducted within specific geographical and occupational settings/groups making results not necessarily representative to the general population. Nonetheless, it provides an overview on the pattern of ZDs which may be useful for specific interventions on such settings.

Brucellosis

Brucellosis imposed higher risk of certain occupation involving close contact with animals.[30] The prevalence is generally higher among abattoir workers (48.4%)[11] as compared to other studies conducted in different region in Tanzania including: Tanga, Mbeya, Katavi-Rukwa and Ngorongoro, with reported prevalence of 5.2%, 1.41%,0.6% and 5.8%, respectively.[8–10,12] Study population, sample size, study area and diagnostic equipment may be associated with difference prevalence among populations at risk.[9,11]People involving in slaughtering activities are at higher risk of exposure to the disease.[8,31] Higher risk of exposure was observed among male compared to female.[8,9]Similar finding was also reported in Uganda and Nigeria.[30,32] This may be due to the fact that activities such as slaughtering are done by male.[8,9,30] Habit of consuming raw animal products shows potential risks for exposure to *brucella* species for both males and females.[33]

Considering that the diagnosis and clinical management of febrile illnesses in Tanzania are done partially due to limited laboratory equipment, resulting in inappropriate treatment and diagnosis of bacterial febrile illnesses.[34,35] Chipwaza et al (2015) on the study at Kilosa district in Tanzania, in which majority are pastoralist, highlighted one point by the fact that 23.0% of the recruited population had malaria parasites, 11.6% had presumptive acute Leptospirosis and 13% had confirmed Leptospirosis, 7% had acute Brucellosis *B. Abortus* and (15.4%) had *B. Melitensis* , 10.3% had presumptive typhoid fever and 18.6% had urinary tract infections of patients.[7] Similar finding was reported by Njeru et al (2016) in Kenya.[36] Low level of educational was associated with prevalence of Brucellosis among occupational workers at higher risk. People with illiteracy or primary education background have inadequate knowledge of zoonotic diseases and work for long hours, which increases risk of exposure to the diseases.[37,38]

Leptospirosis

Leptospirosis is reported as a frequent cause of febrile illness in developing countries. In northern regions of Tanzania, Malaria is uncommon and over-diagnosed with other diseases having similar clinical features.[39,40] Crump et al (2013) reported that leptospirosis accounts for 33.9% of acute febrile illnesses.[16] Having livestock in higher location and contaminated environment by disease pathogens has been associated with prevalence of the diseases in northern region.[39,41]

Leptospirosis was formerly considered to be a primarily occupational disease, and it has been associated with activities such as raw meat processing, livestock farming, butchering and producing veterinary medicine.[15] Close proximity to wildlife areas has associated with spill-over of disease from wildlife to livestock, hence it generates risks of infection to humans.[14,18] Moreover, the higher prevalence that was reported in male than in female can be explained by the occupational/recreational exposures that put men in closer contact with *Leptospira*-infected animals or contaminated water or urine.[42]

Q fever

Q fever is a common cause of febrile illness in Tanzania but is still unclear and under-reported in health facilities.[16] Although being a common febrile illness in some part of Tanzania, Q fever is still misdiagnosis and treated inappropriately.[19] Crump et al (2013), reported prevalence of Q fever at a rate of 20.3%, but the most common diagnosed disease reported was Malaria instead (60.7%).[16] Similarly, the finding was also reported to other studies conducted in Kenya and northern region of Tanzania with the prevalence of 16.2% and 5.2% to patients with febrile illness, respectively.[19,43] There are indications of increasing cases of severe febrile illnesses of under-recognised zoonotic sources facing clinicians, and lacks of diagnostic tools in Tanzania have led to misdiagnosis of familiar febrile illnesses.[43]

Cysticercosis/ Taeniasis

The review demonstrates big variations in prevalence of active infection (**Table 1)** with *T*. *Solium* Cysticercosis across regions of Tanzania with prevalence in two studies carried out by Mbozi (16.7%), which is much higher than the prevalence reported in Dar es Salaam's study (2.7%).[20,21] This variation could be explained by: the exposure expressed by antibody seroprevalence could be interpreted as the result of a past infection, current infection or the result of a failed infection, while circulating antigens can only be detected if viable Cysticerci are present; On the other hand, the presence of circulating *T.Solium* was linked to poor water sanitation and hygiene.[20]

Rift Valley fever

Having close contact with animals and living in areas with water loggings, which facilitates the reproduction of mosquitoes (*Culex* and *Aedes*) vectors, helps accelerate the transmission of Rift Valley Fever in human. Heinrich et al (2012) accounted prevalence of 29.3%.[22] Similar studies also indicated that crowded plant growth and activities requiring close contact with animals such as slaughtering and butchering are associated with Rift Valley fever seropositivity in human.[44]

Other zoonotic diseases included Toxoplasmosis, Echinococcosis, Schistosomiasis, Cryptosporidium and Fascioliasis in Tanzania,[24–29] where a few studies were carried out in such conditions of poor water quality that food and water were contaminated with animal excrete.[45–47] Pastoralist community were also at increased risk due to their habits of raw meat consumption.[25]

Limitation of study

Most of the studies were cross sectional studies with questionnaires and retrospective studies. Due to different sampling designs used to identify epidemiological characteristics of the disease including seroprevalence of zoonotic diseases, there is risk of sampling bias such as information bias and selection bias which may occur during data collection and thus may affect the results.

V. CONCLUSIONS

Zoonotic diseases pose a significant burden in Africa, especially in Tanzania as one of the hot spot for these diseases. Factors such as residence, level of education, occupation, ethnic group and geographical location has shown to contribute in the pattern of zoonotic diseases in Tanzania. Increases of interactions at the human–livestock and human–wildlife interfaces contribute to the transmission of zoonoses. The lack of diagnostic tests and clinical awareness for many zoonotic diseases is concerning, being reflected in the low levels of diagnoses in clinical settings. A 'One Health' approach, which involves the intensive efforts of veterinarians, physicians, public health workers

and epidemiologists, is essential in the policy schemes that are aimed at controlling and preventing the transmission of such diseases.

Authors Contribution Template text

Yuster Lucas Masanja contributed to the conception and design of the study. He also acquired, analyzed and interpreted the data, drafted and revised the manuscript. Dr. Hoang Thi Hai Van contributed for critically revised the manuscript. All authors read and approved the final manuscript.

REFERENCES

1. Grace D, Mutua F, Ochungo P, et al. Mapping of poverty and likely zoonoses hotspots. *Zoonoses Project*. 2012;4:1-119.

2. Grace D, Gilbert J, Randolph T, Kang'ethe E. The multiple burdens of zoonotic disease and an Ecohealth approach to their assessment. *Trop Anim Health Prod*. 2012;44 Suppl 1:S67-73. doi:10.1007/s11250-012-0209-y.

3. Patz Jonathan A., Daszak Peter, Tabor Gary M., et al. Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence. *Environmental Health Perspectives*. 2004;112(10):1092-1098. doi:10.1289/ehp.6877.

4. World Health Organization, United Kingdom. Dept. for International Development. Animal Health Programme, Food and Agriculture Organization of the United Nations, World Organisation for Animal Health. The control of neglected zoonotic diseases: a route to poverty alleviation : report of a joint WHO/DFID-AHP meeting, 20 and 21 September 2005, WHO Headquarters, Geneva, with the participation of FAO and OIE. 2006;(WHO/SDE/FOS/2006.1). Accessed December 24, 2021. https://apps.who.int/iris/handle/10665/43485.

5. Prime minister's office united republic of Tanzania, United States Department of Defense (DoD), Defense Threat Reduction Agency (DTRA), Cooperative Threat Reduction (CTR), Cooperative Biological Engagement Program (CBEP). *The United Republic of Tanzania One Health Strategic Plan 2015 – 2020*. World Health Organization; 2015. Accessed March 15, 2020. http://www.tzdpg.or.tz/fileadmin/documents/dpg_internal/dpg_working_groups_clusters/cluster_2/health/Key_Sector_Documents/Tanzania_Key_Health_Documents/FINAL_URT_One_Health_Strategy_Plan_20151021.pdf.

6. Final_urt_one_health_strategy_plan_20151021.Pdf. Accessed march 15, 2020. Http://www.Tzdpg.Or.Tz/fileadmin/documents/dpg_internal/dpg_working_groups_clusters/cluster_2/health/key_sector_documents/tanzania_key_health_documents/final_urt_one_health_strategy_plan_20151021.Pdf.

7. Chipwaza B, Mhamphi GG, Ngatunga SD, et al. Prevalence of bacterial febrile illnesses in children in Kilosa district, Tanzania. *PLoS Negl Trop Dis*. 2015;9(5):e0003750. doi:10.1371/journal.pntd.0003750.

8. Swai ES, Schoonman L. Human Brucellosis: Seroprevalence and Risk Factors Related to High Risk Occupational Groups in Tanga Municipality, Tanzania. *Zoonoses and Public Health*. 2009; 56(4):183-187. doi:10.1111/j.1863-2378.2008.01175.x.

9. Sagamiko FD, Muma JB, Karimuribo ED, et al. Seroprevalence of human Brucellosis and associated risk factors among high risk occupations in Mbeya Region of Tanzania. *bioRxiv*. Published online July 1, 2019:688705. doi:10.1101/688705.

10. Assenga JA, Matemba LE, Muller SK, Malakalinga JJ, Kazwala RR. Epidemiology of Brucella infection in the human, livestock and wildlife interface in the Katavi-Rukwa ecosystem, Tanzania. *BMC Vet Res*. 2015;11(1):189. doi:10.1186/s12917-015-0504-8.

11. Mirambo MM, Mgode GF, Malima ZO, et al. Seropositivity of Brucella spp. and Leptospira spp. antibodies among abattoir workers and meat vendors in the city of Mwanza, Tanzania: A call for one health approach control strategies. *PLoS Negl Trop Dis*. 2018;12(6). doi:10.1371/journal.pntd.0006600.

12. Nonga HE, Mwakapeje ER. Trends of human brucellosis in pastoralist communities based on hospital records during 2013–2016 in Ngorongoro District, Tanzania. *Tanzania Veterinary Journal*. 2017; 32(1):34-40. doi:10.4314/tvj.v32i1.

13. John K, Fitzpatrick J, French N, et al. Quantifying Risk Factors for Human Brucellosis in Rural Northern Tanzania. *PLOS ONE*. 2010; 5(4):e9968. doi:10.1371/journal.pone.0009968.

14. Assenga JA, Matemba LE, Muller SK, Mhamphi GG, Kazwala RR. Predominant Leptospiral Serogroups Circulating among Humans, Livestock and Wildlife in Katavi-Rukwa Ecosystem, Tanzania. *PLoS Negl Trop Dis*. 2015;9(3). doi:10.1371/journal.pntd.0003607.

15. Mgode GF, Japhary MM, Mhamphi GG, Kiwelu I, Athaide I, Machang'u RS. Leptospirosis in sugarcane plantation and fishing communities in Kagera northwestern Tanzania. *PLoS Negl Trop Dis*. 2019; 13(5). doi:10.1371/journal.pntd.0007225.

16. Crump JA, Morrissey AB, Nicholson WL, et al. Etiology of Severe Non-malaria Febrile Illness in Northern Tanzania: A Prospective Cohort Study. *PLOS Neglected Tropical Diseases*. 2013;7(7):e2324. doi:10.1371/journal.pntd.0002324.

17. Schoonman L, Swai ES. Risk factors associated with the seroprevalence of leptospirosis, amongst at-risk groups in and around Tanga city, Tanzania. *Annals of Tropical Medicine & Parasitology*. 2009;103(8):711-718. doi:10.1179/000349809X12554106963393.

18. Muller SK, Assenga JA, Matemba LE, Misinzo G, Kazwala RR. Human leptospirosis in Tanzania: sequencing and phylogenetic analysis confirm that pathogenic Leptospira species circulate among agro-pastoralists living in Katavi-Rukwa ecosystem. *BMC Infect Dis*. 2016;16:273. doi:10.1186/s12879-016-1588-x.

19. Prabhu M, Nicholson WL, Roche AJ, et al. Q Fever, Spotted Fever Group, and Typhus Group Rickettsioses Among Hospitalized Febrile Patients in Northern Tanzania. *Clin Infect Dis*. 2011; 53(4):e8-e15. doi:10.1093/cid/cir411.

20. Mwanjali G, Kihamia C, Kakoko DVC, et al. Prevalence and Risk Factors Associated with Human Taenia Solium Infections in Mbozi District, Mbeya Region, Tanzania. *PLoS Negl Trop Dis*. 2013; 7(3). doi:10.1371/journal.pntd.0002102.

21. Schmidt V, O'Hara MC, Ngowi B, et al. Taenia solium cysticercosis and taeniasis in urban settings: Epidemiological evidence from a health-center based study among people with epilepsy in Dar es Salaam, Tanzania. *PLoS Negl Trop Dis*. 2019;13(12). doi:10.1371/journal.pntd.0007751.

22. Heinrich N, Saathoff E, Weller N, et al. High Seroprevalence of Rift Valley Fever and Evidence for Endemic Circulation in Mbeya Region, Tanzania, in a Cross-Sectional Study. *PLoS Negl Trop Dis*. 2012;6(3). doi:10.1371/journal.pntd.0001557.

23. Ahmed A, Makame J, Robert F, Julius K, Mecky M. Sero-prevalence and spatial distribution of Rift Valley fever infection among agro-pastoral and pastoral communities during Interepidemic period in the Serengeti ecosystem, northern Tanzania. *BMC Infect Dis*. 2018;18. doi:10.1186/s12879-018-3183-9

24. Lukambagire AHS, Mchaile DN, Nyindo M. Diagnosis of human fascioliasis in Arusha

region, northern Tanzania by microscopy and clinical manifestations in patients. *BMC Infect Dis*. 2015;15. doi:10.1186/s12879-015-1326-9.

25. Khan MB, Sonaimuthu P, Lau YL, et al. High seroprevalence of echinococossis, schistosomiasis and toxoplasmosis among the populations in Babati and Monduli districts, Tanzania. *Parasit Vectors*. 2014; 7. doi:10.1186/s13071-014-0505-7.

26. Mugono M, Konje E, Kuhn S, Mpogoro FJ, Morona D, Mazigo HD. Intestinal schistosomiasis and geohelminths of Ukara Island, North-Western Tanzania: prevalence, intensity of infection and associated risk factors among school children. *Parasit Vectors*. 2014; 7. doi:10.1186/s13071-014-0612-5.

27. Mazigo HD, Kirway L, Ambrose EA. Prevalence and intensity of Schistosoma mansoni infection in pediatric populations on antiretroviral therapy in north-western Tanzania: a cross-sectional study. *BMJ Open*. 2019; 9(7). doi:10.1136/bmjopen-2019-029749.

28. Said K, Hella J, Knopp S, et al. Schistosoma, other helminth infections, and associated risk factors in preschool-aged children in urban Tanzania. *PLoS Negl Trop Dis*. 2017; 11(11). doi:10.1371/journal.pntd.0006017

29. Parsons MB, Travis D, Lonsdorf EV, et al. Epidemiology and Molecular Characterization of Cryptosporidium spp. in Humans, Wild Primates, and Domesticated Animals in the Greater Gombe Ecosystem, Tanzania. *PLoS Negl Trop Dis*. 2015; 9(2). doi:10.1371/journal.pntd.0003529.

30. Igawe PB, Okolocha E, Kia GS, Bugun II, Balogun MS, Nguku P. Seroprevalence of brucellosis and associated risk factors among abattoir workers in Bauchi State, Nigeria. *The Pan African Medical Journal*. 2020; 35(33). doi:10.11604/pamj.2020.35.33.18134.

31. Acharya D, Hwang SD, Park JH. Seroreactivity and Risk Factors Associated with Human Brucellosis among Cattle Slaughterhouse Workers in South Korea. *Int J Environ Res Public Health*. 2018;15(11). doi:10.3390/ijerph15112396.

32. Tumwine G, Matovu E, Kabasa JD, Owiny DO, Majalija S. Human brucellosis: sero-prevalence and associated risk factors in agro-pastoral communities of Kiboga District, Central Uganda. *BMC Public Health*. 2015;15. doi:10.1186/s12889-015-2242-z.

33. Makala R, Majigo MV, Bwire GM, Kibwana U, Mirambo MM, Joachim A. Seroprevalence of Brucella infection and associated factors among pregnant women receiving antenatal care around human, wildlife and livestock interface in Ngorongoro ecosystem, Northern Tanzania. A cross-sectional study. *BMC Infectious Diseases*. 2020; 20(1): 152. doi:10.1186/s12879-020-4873-7.

34. Saddique A, Ali S, Akhter S, et al. Acute Febrile Illness Caused by Brucella Abortus Infection in Humans in Pakistan. *Int J Environ Res Public Health*. 2019; 16(21). doi:10.3390/ijerph16214071.

35. Bouley AJ, Biggs HM, Stoddard RA, et al. Brucellosis among Hospitalized Febrile Patients in Northern Tanzania. *Am J Trop Med Hyg*. 2012; 87(6): 1105-1111. doi:10.4269/ajtmh.2012.12-0327.

36. Njeru J, Melzer F, Wareth G, et al. Human Brucellosis in Febrile Patients Seeking Treatment at Remote Hospitals, Northeastern Kenya, 2014–2015. *Emerg Infect Dis*. 2016; 22(12): 2160-2164. doi:10.3201/eid2212.160285.

37. Tsegay A, Tuli G, Kassa T, Kebede N. Seroprevalence and risk factors of brucellosis in abattoir workers at Debre Zeit and Modjo

export abattoir, Central Ethiopia. *BMC Infect Dis*. 2017;17. doi:10.1186/s12879-017-2208-0.

38. Madut NA, Ocan M, Muwonge A, et al. Sero-prevalence of brucellosis among slaughterhouse workers in Bahr el Ghazal region, South Sudan. *BMC Infectious Diseases*. 2019; 19(1):450. doi:10.1186/s12879-019-4066-4.

39. Biggs HM, Hertz JT, Munishi OM, et al. Estimating Leptospirosis Incidence Using Hospital-Based Surveillance and a Population-Based Health Care Utilization Survey in Tanzania. *PLoS Negl Trop Dis*. 2013; 7(12). doi:10.1371/journal.pntd.0002589.

40. Rafizah AAN, Aziah BD, Azwany YN, et al. A hospital-based study on seroprevalence of leptospirosis among febrile cases in northeastern Malaysia. *International Journal of Infectious Diseases*. 2013; 17(6):e394-e397. doi:10.1016/j.ijid.2012.12.012.

41. Biggs HM, Bui DM, Galloway RL, et al. Leptospirosis among Hospitalized Febrile Patients in Northern Tanzania. *Am J Trop Med Hyg*. 2011; 85(2):275-281. doi:10.4269/ajtmh.2011.11-0176.

42. Dreyfus A, Dyal JW, Pearson R, et al. Leptospira Seroprevalence and Risk Factors in Health Centre Patients in Hoima District, Western Uganda. *PLOS Neglected Tropical Diseases*. 2016; 10(8): e0004858. doi:10.1371/journal.pntd.0004858.

43. Njeru J, Henning K, Pletz MW, et al. Febrile patients admitted to remote hospitals in Northeastern Kenya: seroprevalence, risk factors and a clinical prediction tool for Q-Fever. *BMC Infect Dis*. 2016; 16. doi:10.1186/s12879-016-1569-0.

44. Ahmed A, Makame J, Robert F, Julius K, Mecky M. Sero-prevalence and spatial distribution of Rift Valley fever infection among agro-pastoral and pastoral communities during Interepidemic period in the Serengeti ecosystem, northern Tanzania. *BMC Infect Dis*. 2018; 18(1): 276. doi:10.1186/s12879-018-3183-9.

45. Khan MB, Sonaimuthu P, Lau YL, et al. High seroprevalence of echinococossis, schistosomiasis and toxoplasmosis among the populations in Babati and Monduli districts, Tanzania. Published online 2014:9.

46. Mazigo HD, Kirway L, Ambrose EA. Prevalence and intensity of *Schistosoma mansoni* infection in pediatric populations on antiretroviral therapy in north-western Tanzania: a cross-sectional study. *BMJ Open*. 2019; 9(7): e029749. doi:10.1136/bmjopen-2019-029749.

47. Said K, Hella J, Knopp S, et al. Schistosoma, other helminth infections, and associated risk factors in preschool-aged children in urban Tanzania. Downs JA, ed. *PLoS Negl Trop Dis*. 2017; 11(11): e0006017. doi:10.1371/journal.pntd.0006017.