Plague in Tanzania: an overview

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Abstract: Human plague remains a public health concern in Tanzania despite its quiescence in most foci for years, considering the recurrence nature of the disease. Despite the long-standing history of this problem, there have not been recent reviews of the current knowledge on plague in Tanzania. This work aimed at providing a current overview of plague in Tanzania in terms of its introduction, potential reservoirs, possible causes of plague persistence and repeated outbreaks in the country. Plague is believed to have been introduced to Tanzania from the Middle East through Uganda with the first authentication in 1886. *Xenopsylla brasiliensis, X. cheopis, Dinopsyllus lypusus,* and *Pulex irritans* are among potential vectors while *Lophuromys spp, Praomys delectorum, Graphiurus murinus, Lemniscomys striatus, Mastomys natalensis,* and *Rattus rattus* may be the potential reservoirs. Plague persistence and repeated outbreaks in Tanzania are likely to be attributable to a complexity of factors including cultural, socio-economical, environmental and biological. Minimizing or preventing people's proximity to rodents is probably the most effective means of preventing plague outbreaks in humans in the future. In conclusion, much has been done on plague diagnosis in Tanzania. However, in order to achieve new insights into the features of plague epidemiology in the country, and to reorganize an effective control strategy, we recommend broader studies that will include the ecology of the pathogen, vectors and potential hosts, identifying the reservoirs, dynamics of infection and landscape ecology.

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Keywords: plague, history, outbreaks, persistence, reservoirs, Tanzania

Introduction

Human plague remains the oldest epidemic bacterial infection in human history and among the three epidemic-prone diseases that are still of major public health importance globally and which are subject to international health regulations and notifiable to the World Health Organization (WHO, 2000; 2005). The plague cycle can be murine, involving rodents, fleas, humans and other mammals (e.g. cats, rabbits and dogs) or sylvatic, involving wild rodents and/or other small mammals. Sylvatic plague is widely distributed in western North America, South America, Southern, Eastern and Central Africa, Middle East and Central Asia (WHO, 2006). The disease spreads to humans and other animals through fleas infected with the causative agent, *Yersinia pestis*. Human transmission occurs when these fleas escape from plague infected rodents and bite humans. Human to human transmission of *Y. pestis* can also be caused by house fleas, especially *Pulex irritans*. Plague can also be transmitted through direct contagion with plague infected materials, inhalation of dusts containing *Y. pestis* or droplets expelled by coughing of a pneumonic plague-infected person or animal especially house cats (WHO, 2000; CDC, 2012). Plague persists as a chronic disease among many species of rodents that harbor fleas that are responsible for maintaining transmission and outbreaks often occur in unpredictable patterns. Globally, over 200 mammalian species in 73 genera have been reported to be naturally infected with *Y. pestis*, but rodents are the most important hosts (Perry & Fetherston, 1997).

In Africa, countries most affected include Madagascar, Democratic Republic of Congo, Mozambique, Uganda and Tanzania. In Tanzania from 1980 to 2011, a total of 8,490 plague cases with

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675 (8.0%) deaths were reported (Ziwa *et al.,* 2013). Outbreaks in Algeria and elsewhere including Tanzania and Zambia have shown that plague may re-emerge in the same areas after a long period of silence (WHO, 2004; Makundi *et al.,* 2008; Hang'ombe *et al.,* 2012) and hence an effective disease surveillance needs to be emphasized.

The aim of this study was to review the current knowledge on the introduction of plague, possible causes of repeated outbreaks and potential reservoirs in Tanzania. The study was accomplished by compiling information from published sources, internet searches and through personal consultations with some researchers working on plague.

Plague introduction, outbreaks and spread in Tanzania

Tanzania has a well documented history of plague covering about 127 years (Msangi, 1969; Makundi *et al.,* 2008). The disease has been endemic in many parts of the country since pre-colonial times. It is believed that plague could have been introduced to Tanzania and other countries in Eastern, Central and Southern Africa from the Middle East or India by various medieval traders including slave and ivory caravans and/or via pilgrims to and from Egypt and Saudi Arabia long before the occurrence of the first recorded outbreak in the region (Kilonzo, 1976; WHO, 2000). During the 18th and 19th centuries epidemics alleged to be plague occurred in various localities around Lake Victoria as well as southern and southeastern Kenya (Roberts, 1935 as cited in Neerinckx *et al.,* 2012).
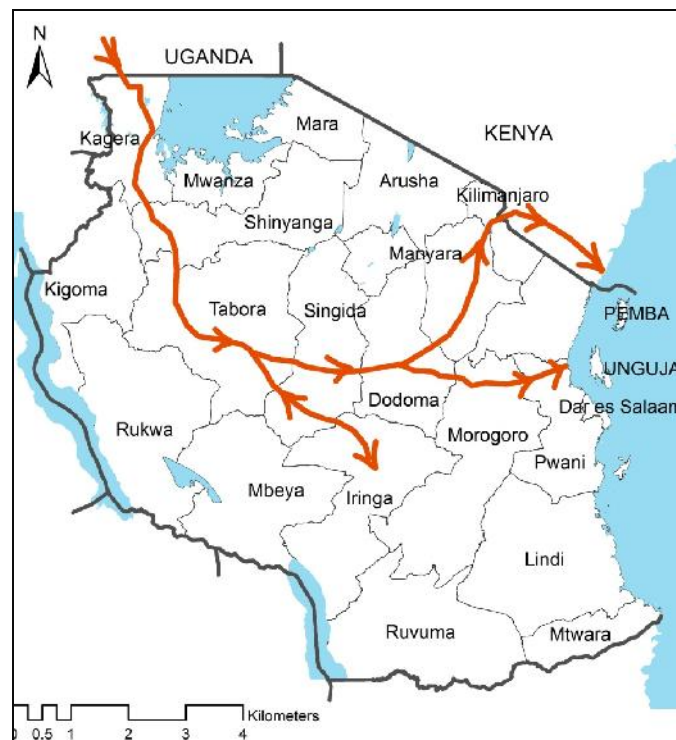

Figure 1: Plague introduction and spread in Tanzania

The first recorded outbreak in Eastern Africa occurred in Mombasa in 1697 and was believably introduced from Oman (Roberts, 1935 as cited in Neerinckx *et al.,* 2012). However, the earliest authentically recorded outbreak of plague in East Africa occurred in Uganda in 1877 and reported by Missionaries who noted that the disease was already familiar to the Buganda people and was locally referred to as "kawumpuli" (Orochi, 2002). Slave and ivory caravan routes usually extended from the

Buganda Kingdom in Uganda where plague was endemic to Tanzania via Kagera (Msangi, 1975). Nevertheless, the disease was authenticated for the first time in the Tanzania in 1886 when an epidemic was reported by German doctors at Image in Iringa district, south-west Tanzania (Kilonzo *et al.,* 2005). According to historical data however, there was a possibility that, plague already existed in the Kagera area even before the 1886 outbreak. This is attributable to the facts that plague was introduced to this area from Uganda, that at the time (1887) of disease authentication at Kiziba in Bukoba District in Kagera region and isolation of the causative agent (*Y. pestis*) from patients in the area, the local people were already familiar with the disease and referred to it as "rubunga" meaning sporadic disease, and they had developed some control and preventive methods which included isolation of patients and abandonment of houses with plague cases (Kilonzo *et al.,* 2005).
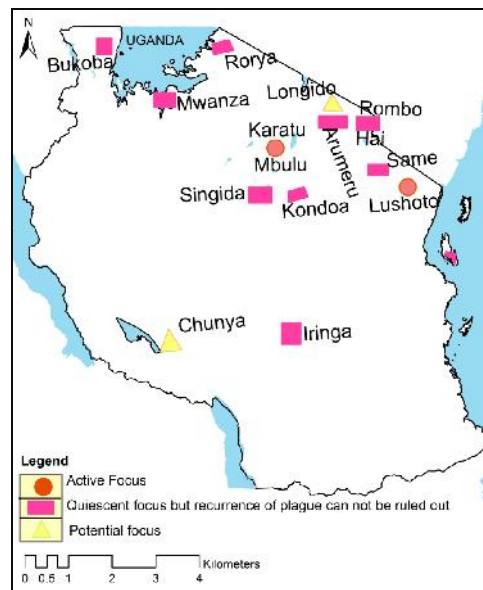

Figure 2: Plague foci in Tanzania

In Tanzania the disease spread southwards along the slave and ivory trade caravan routes from Kagera to Tabora and then to Iringa and eastwards to the coast via Singida and Dodoma (Figure 1). While the eastwards spread was believably facilitated by slave and ivory trade caravans, the southward spread was probably facilitated by tribal wars between Hehe warriors and other tribes. Spread of the disease from Central Tanzania to the north-eastern zone including Kilimanjaro and Arusha was reportedly facilitated by slave trade caravans which resulted from an agreement between the local chiefs in northern Tanzania and the Arab Sultan for supplying slaves (B.S. Kilonzo-unpublished data). Since then the disease spread and became endemic in different parts of the country especially along the ancient slave trade routes. These include Iringa, Singida, Kondoa, Rombo, Hai, Arumeru, Mbulu and Same districts (Figure 2) where several outbreaks occurred at various times and involved varying numbers of human cases and deaths (Kilonzo *et al.,* 2006).

The plague outbreak in Lushoto district in 1980 was believed to have been introduced from southern Kenya where it was then prevalent by a business man who had been visiting both places for prior to his illness and subsequent death (Kenya, 1978; Kilonzo & Mhina, 1982). Some researchers argue that plague was enzootic in the district and when the deforestation was taking place in the 1960-1970s there was greater interaction between rodents, fleas and humans which facilitated the transfer of the pathogen to humans resulting into the first outbreaks in the early 1980s. Others argue that such introduction of the disease to Lushoto could have been caused by the immigrants who

came into the district in large numbers in the 1960s whereby some of these arrived from the Pare Mountains and could have virtually carried with them pestiferous fleas and rodents, which got established and took several years before humans were infected.

In Lushoto, plague outbreaks have occurred yearly from 1980 to 2003 and involved the largest number of recorded cases and deaths in the country (Table 1). In 1996 another outbreak was reported in Karatu which involved 186 clinically suspected cases with 12 (6.5%) deaths (Kilonzo *et al.,* 2006). The introduction of plague to Karatu was allegedly caused by transportation of infected materials, particularly fruits from Lushoto where the disease had been prevalent since 1980. However, a possibility that the pathogen could have been introduced from the neighbouring Mbulu district which harbours a long-standing focus could not be ruled out (Kilonzo & Mtoi, 1983). Moreover, Karatu was, until recently, part of Mbulu district and communities in the two districts are closely related culturally, socially and economically. Records show that all the foci in Tanzania have experienced several outbreaks of the disease at one time or another and involved large numbers of human cases and substantial case-fatality rates; with Mbulu district reporting the most recent outbreaks (Kilonzo *et al.,* 1997, 2006; Makundi *et al.,* 2008; Ziwa *et al.,* 2013).

Table 1: Number of cases, death and percentage of deaths due to plague in Tanzania, 1980-2011

District	Number of cases	Number of deaths	Percent of deaths
Lushoto	7907	640	8.1
Karatu	197	14	7.1
Mbulu	190	19	10.1
Singida	196	2	1.0

Potential vectors and hosts/reservoirs

Plague outbreaks in an endemic focus not only depend on active interactions between potential mammalian (wild and commensal) hosts/reservoirs and efficient vectors of *Y. pestis* but also on some ecological factors, which determine plague seasonality, occurrence or non occurrence of the disease in some years while in some there are no outbreaks (Makundi *et al.,* 2003). Studies in various endemic foci of the disease in Tanzania have shown involvement of different flea and mammalian species as vectors and hosts/reservoirs of the disease respectively. Studies in Mbulu district showed that wild rodents (*Lophuromys flavopunctatus*, *Praomys delectorum*, *Graphiurus murinus*, *Lemniscomys striatus*) and commensal and semi-domestic rats respectively (*Rattus rattus* and *Mastomys natalensis*) were the potential suspected reservoirs/hosts of *Y. pestis* in the focus while *Xenopsylla brasiliensis* and *Dinopsyllus lypusus* were the major potential vectors during an outbreak in 2007 (Makundi *et al.,* 2008). These observations were consistent with observations on studies carried out in the district soon after the 1977 plague outbreak (Kilonzo & Mtoi, 1983). Furthermore, a study by Kilonzo *et al.* (2006) also revealed predominance of *Xenopsylla brasiliensis* (45.8%) and *Dinopsyllus lypusus* (54.2%) on plague-positive rodents in Karatu district, which is adjacent to Mbulu district. On the other hand, Laudisoit *et al.* (2007) reported a direct correlation between flea indices and plague incidence in endemic villages in Lushoto district which reported plague outbreaks for 23 years since 1980 and which had been extensively studied. Moreover, in the same focus, earlier studies showed that *Mastomys natalensis, Lophuromys flavopunctatus, Arvicanthis nairobe* and *Rattus rattus* were serologically positive for plague suggesting that they had been previously exposed to *Y. pestis* infection and that they were probably the natural reservoirs/hosts of the disease in the area (Kilonzo *et al.,* 2005). Furthermore, the authors using ELISA tests demonstrated that such reservoirs were widely distributed in Tanzania.

Possible causes of disease persistence and repeated outbreaks in endemic foci

The current scientific thinking is that plague persists for long periods of time at low to very low levels of prevalence in enzootic cycles that cause little host mortality and involve partially resistant rodents (enzootic hosts). The long periods are punctuated by occasional outbursts or epizootics among these hosts or epidemics, when the incidence among humans increases (Ben-Ari *et al.,* 2011). However, a multitude of factors including human activities and behaviour, climatic changes and globalization have been reported to be the contributing factors to such disease patterns.

Human activities and behaviour

Plague transmission in Tanzania and elsewhere is usually seasonal and in some foci outbreaks normally occur in November to March and peaks are observed between December and February with strong inter-annual variations (WHO, 2006). Such a seasonality pattern could either be attributed to climatic factors or socio-economic activities that expose hosts to infective vectors (Njunwa *et al.,* 1989; Makundi & Kilonzo, 1994). Human exposure to plague can be a result of human activities in natural or artificial ecological systems. Human disruption of even part of macro or micro ecological system through agricultural activities, grazing livestock, timber industry or any other activity has wide ranging effects on many species including rodents that naturally and permanently live in these ecological systems and can have consequences on public and animal health including increase of risks for emergence and outbreaks of diseases. It can also affect primary production and even fundamental climate cycles in an area. Furthermore, the movement of humans, domestic animals and wildlife populations, drive land use changes that in turn drive infectious disease emergence (Daszak *et al.,* 2000). The emerging infectious diseases (EIDs) resulting from land use change may occur either from "spillover" or cross-species transmission through co-habitation or simply by extension of geographic range into new or changed habitats. (Taylor *et al.,* 2001). In addition, interventions of the natural ecological systems causes overlaps in the habitats of sylvatic and domestic or peridomestic rodent species with increased interactions with humans, rodents and fleas thus facilitating plague epidemics (WHO, 2006).

Gender and age variation in the incidence of plague has been observed. Studies in some endemic foci in Tanzania have shown incidence profiles with a higher prevalence in women than in men in the age group 30-60 years. The incidence among children aged 5-14 years has been reported to be twice that among adult women (Davis *et al.,* 2006). Socio-cultural and economic factors influence the incidence of plague in families and within the community. Females and children are actively involved in production activities such as collecting firewood from the nearby forests, farming and grazing livestock. Socially it has been documented that females and children in large families with inadequate numbers of beds, do sleep on the floor (Kilonzo *et al.,* 1997). This habit might contribute to predisposing the group to flea bites and hence the high infection rate (Kamugisha *et al.,* 2007). Low basic education on the other hand has a negative impact on the level of understanding of health education by villagers. Belief in witchcraft has also been claimed to be responsible for delayed treatment and lack of proper treatment, and the social stigma associated with plague prevents families from seeking medical attention, they thus resort to self-medication (WHO, 2008).

Land use and change in landscape structure caused by human activities may affect plague dynamics by significantly altering the composition of ecological communities of both vector and potential *Y. pestis* hosts, thereby altering key ecological interactions involved in pathogen transmission pathways. Such phenomenon has been witnessed in the two plague active foci of Mbulu and Lushoto in Tanzania where there is greater encroachment into natural wild rodent habitats which lead to more frequent contacts between wild and domestic rodents, thus facilitating

transfer of both fleas and the plague bacteria and hence human infection (Collinge *et al.* 2005; Ben Ari *et al*. 2011).

Climate changes and plague outbreaks

The plague system is the result of complex interactions between its components, the densities, life cycle, dynamics and geographical distributions all of which are individually influenced by climate variables. Climate variables influence the dynamics of flea vectors and rodent hosts with responses varying considerably among species (Meserve *et al.,* 1995; Gubler *et al.,* 2001). Climate has long been suspected to be a key factor in the alternation between quiescent and active periods of plague. Davis (1953) showed that human plague outbreaks in several African countries were less frequent when the weather was too hot (>27°C) or very cold (<15°C). Njunwa *et al.* (1989) and Ben-Ari *et al.,* (2011) similarly, reported that outbreaks of the disease usually occur when ambient temperatures are suitable for flea multiplication. Reportedly, abundance of rodent fleas is affected by ambient temperatures, rainfall, and relative humidity, with warm-moist weather providing a likely explanation for higher flea indices (Ben-Ari *et al.,* 2011). Indeed, temperature, rainfall, and relative humidity have direct effects on development and survival, as well as the behaviour and reproduction of fleas and their populations (Krasnov *et al.,* 2001; 2002; Gage *et al.,* 2008). The rate of metamorphosis of *X. cheopis* and *X. brasiliensis*, from egg to adult is regulated by temperature.

Fleas are ecto-thermic and hence sensitive to temperature fluctuations, a behaviour that is enhanced by the fact that all the immature stages of the insects are free living. Flea development rates increase with temperature until they reach a critical value; then the survival of immature stages decreases if high temperatures are combined with low humidity (Gage *et al.,* 2008). Survival of immature stages of fleas in rodent burrows is also affected by soil moisture that is partly controlled by outside precipitation (Eisen, 2009) even though detrimental moisture losses and temperature swings are reduced by living underground (Krasnov *et al.,* 2001). Conversely, when coupled with a high organic load, excessively wet conditions in rodent burrows (e.g. relative humidity >95%) can promote the growth of destructive fungi that diminish larval and egg survival (Parmenter, 1999; Ben-Ari *et al.,* 2011). Since transmission of plague from rodent reservoirs/hosts to humans and consequent occurrence of outbreaks of the disease is very much facilitated by high flea indices, it is obvious that climatic factors affecting survival and production of the insects have some positive or negative effects on outbreaks of the disease.

Rodent survival and population dynamics are also affected by climate. A direct effect occurs when heavy rainfall causes flooding of rodent burrows (Ben-Ari *et al.,* 2011), but the effects of precipitation on rodent densities are mostly bottom-up (Meserve *et al.,* 2001). Indeed, rainfall controls primary production which limits rodent abundances (Letnic *et al.,* 2005). Reproduction and recruitment periods often follow wet seasons when increases of primary production can be used to build up juvenile populations (Jaksic, 2003). Accordingly, rodent population densities show clear association with annual rainfall and its seasonal distribution (Leirs *et al.,* 1996; Ben-Ari *et al.,* 2011). The relationship between precipitation patterns and rodent densities can be complex, localized, and dependent on the timing and the intensity of precipitation events (Gubler *et al.,* 2001; Brown, 2002). In Tanzania, studies by Davis *et al.* (2006) have shown that rodent population densities show clear association with annual rainfall and its seasonal distribution. However, temperature effects on rodent populations are less clear in part because rodents are homeothermic and hence do not respond immediately to changes in ambient temperatures (Ben-Ari *et al.,* 2011). In practice, the risk of spread of plague from rodents to humans is related to the density of rodents (especially the commensal species), the number of fleas per animal (flea index), and the rate of *Y. pestis* infection in the rodents and fleas due to increased human-rodent-flea interactions (Dennis &

Mead, 2010). It therefore follows that climate effects on rodents have direct or indirect correlation with plague outbreaks in an area.

Conclusion

Substantial research on plague has been done by various researchers in Tanzania. However, the current thinking is based on the hypothesis that plague bacteria circulate at low rates within populations of certain rodents without causing excessive rodent die-off whereby the infected animals and their fleas serve as long-term reservoirs for the bacteria (enzootic cycle) and occasionally, other species become infected, causing an outbreak among animals (epizootic). In order to achieve new insights into the features of plague epidemiology in the country, and to reorganize an effective control strategy, we recommend broader studies that will include the ecology of the pathogen, potential vectors and hosts, determining dynamics of infection i.e. where the pathogen survives during quiescent periods, what activates infection, and Landscape ecology and how it influences infections.

Acknowledgements

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