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Informing surveillance for the lowland plague focus in Azerbaijan using a historic dataset

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A B S T R A C T

Yersinia pestis is a gram-negative, zoonotic bacterium and the causative agent of plague. Plague is maintained in nature through a transmission cycle between partially resistant rodent hosts and fleas. There are natural reservoir populations on almost every continent, and the number of reported human plague cases has increased in recent years. Azerbaijan is a country at the crossroads of Eastern Europe and western Asia that has a history of environmental plague foci. Informing plague surveillance in this region is imperative due to the deteriorating public health system that resulted from the collapse of the Soviet Union. The aim of this study was to inform efforts to prioritize regions for plague surveillance in Azerbaijan. A 14-year historic data set was employed to analyze the spatio-temporal pattern of the primary plague host in the country, the Libyan gird, *Meriones libycus*, using the Space Time Analysis of Moving Polygons (STAMP) method. This method is useful for identifying areas of stable rodent abundance across the study period. The relationship between STAMP-defined stable *M. libycus* abundance and environmental variables including mean temperature, altitude, land cover type and annual precipitation was explored. We were particularly interested in identifying increasing human population trends in the area surrounding regions characterized by historically high *M. libycus* abundance, as the risk of human plague increases as humans come into close proximity with hosts and vectors. There was variation in *M. libycus* abundance over the historic period, but regions of stability were identified for each category of abundance evaluated. There were significantly different climatic conditions and land cover types associated with different categories of abundance. The human population in Azerbaijan has steadily increased over the past 30 years, including regions bordering plague foci. Surveillance should be prioritized for regions with historically stable high host abundance, regions with climatic conditions associated with high abundance, and regions with increasing human populations surrounding plague foci.

Introduction

Plague is a flea borne zoonosis caused by the gram negative bacterium *Yersinia pestis* (Gage & Kosoy, 2005; Perry & Fetherston, 1997; Pollitzer, 1954), which has been associated with three pandemics throughout history (Gage & Kosoy, 2005). Since the onset of the most recent pandemic, which started in China during the mid-nineteenth century, the geographic range of plague has greatly expanded (Gage & Kosoy, 2005). The bacterium is maintained in nature through a transmission cycle between partially resistant rodent hosts and adult hematophagous fleas (Gage & Kosoy, 2005; Meyer, 1942). *Y. pestis* foci can be maintained indefinitely in enzootic or maintenance cycles as long as sufficient numbers of rodent hosts and flea vectors are present (Beran, 1994; Gage & Kosoy, 2005; Gage, Ostfeld, & Olson, 1995).

Natural plague reservoirs are active in Asia, and parts of the Russian Federation (Gratz, 1999). Human plague cases have recently reemerged in this region (Pollitzer, 1954). During the past decade human plague cases have been reported in Saudi Arabia (Saeed, Al-Hamdan, & Fontaine, 2005), Jordan (Arbaji et al., 2005), Afghanistan (Leslie et al., 2011), Algeria (Bertherat et al., 2007) and a limited outbreak in Libya (Tarantola, Mollet, Gueguen, Barboza, & Bertherat, 2009). The reemergence of

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human plague in these areas suggests that there are still active environmental reservoirs, or foci.

Azerbaijan is a country at the crossroads of western Asia and Eastern Europe that has three well documented historical plague foci (Gurbanov & Akhmedova, 2010). Concern about plague has a long history in Azerbaijan. During the Soviet era, the Anti–plague system (APS) was created to respond to outbreaks of plague and other bacterial and viral diseases (Ouagrham-Gormley, 2006; Zilinskas, 2006). As part of routine surveillance and control in Azerbaijan, detailed yearbooks were published annually. The yearbooks outline many aspects of the APS efforts and provide a unique opportunity to better understand the dynamics of plague within the country. This is particularly relevant given the limited resources for surveillance following the collapse of the Soviet Union in 1991. With fewer resources available, detailed historic datasets can be used to help inform current plague surveillance efforts.

In order to successfully monitor and control plague on the landscape it is necessary to understand the distribution and abundance of hosts (Gage & Kosoy, 2005; Stenseth et al., 2008). The Libyan gerbil, *Meriones libycus*, is a major plague host in central and southwest Asia (Bakanidze et al., 2010; Gage & Kosoy, 2005; Gratz, 1999; Gurbanov & Akhmedova, 2010) with a natural range that spans from the Western Sahara to Western Xinjiang, China (Nowak & Paradiso, 1999). As early as 1953, *M. libycus* abundance was linked to a plague epizootic in the Absheron peninsula of Azerbaijan (Bakanidze et al., 2010). Home ranges vary between 50 and 120 m in diameter (Nowak & Paradiso, 1999). *M. libycus* is a ground dwelling gerbil that lives in complex, multi entranced burrows and many individuals may burrow in the same vicinity (Naumov, Lobachev, Dmitriev, Kanatov Iu, & Smirin, 1973). Their preferred burrow location is under bush cover (Dcly & Daly, 2009), which puts them at close proximity to flea vectors (Gage & Kosoy, 2005).

Identifying regions of historically stable plague host presence on the landscape could provide important insight to current host distribution across Azerbaijan. The Space Time Analysis of Moving Polygons (STAMP) approach is one method for addressing these objectives with data such as those available in the APS yearbooks. STAMP uses polygons representing a phenomenon from two consecutive time periods and describes the type of change that is taking place. The analysis includes the identification of regions that do not change, or that remain stable (Robertson, Nelson, Boots, & Wulder, 2007).

Exploring historical changes in *M. libycus* spatial patterns and abundance across the landscape can provide important insight into the distribution and ecology of this important plague host. It is also important to consider the relationship between these spatial patterns and environmental variables, as links have been made between climatic conditions and the presence of plague hosts throughout history (Ben Ari et al., 2011; Davis, 1953; Neerinckx, Bertherat, & Leirs, 2010; Perry & Fetherston, 1997; Stenseth et al., 2006). The distribution of plague hosts may be partially limited by variables such as rainfall, temperature and elevation (Ben Ari et al., 2011). One study presented a trophic cascade hypothesis where precipitation resulted in increased plant production and rodent food sources (Parmenter, Yadav, Parmenter, Ettestad, & Gage, 1999). Locally, there may also be negative associations with increased rainfall. Cavanaugh and Marshall (1972) suggested that high intensity rainfall is detrimental to rodent survival, as burrows may become flooded. There is a less apparent direct relationship between hosts and temperature although in temperate regions, low winter temperatures can impact food availability subsequently influencing rodent density and distribution (Korslund & Steen, 2005). An analysis of the relationship between environmental variables and the persistence of plague hosts in Azerbaijan is included in this analysis.

Research has also suggested that large rodent host populations increases the likelihood of epizootics and human cases (Parmenter et al., 1999). Therefore, understanding the distribution of plague hosts may also allow for better assessments of human risk. In the southwest United States distance to host habitat was a significant

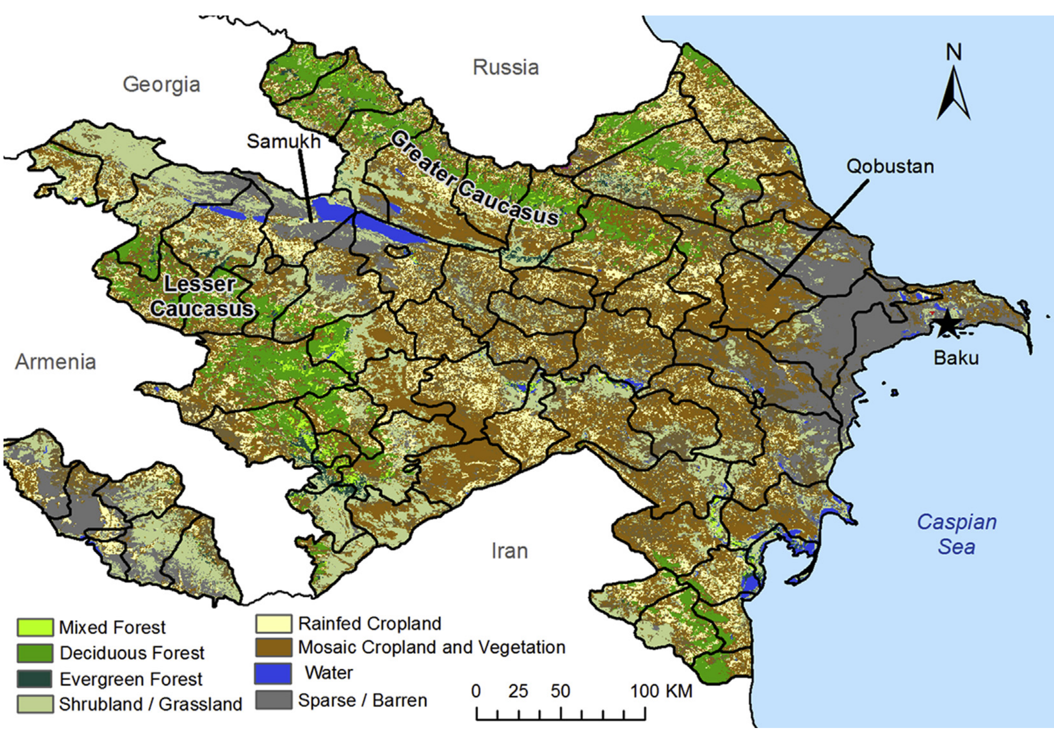

Fig. 1. Azerbaijan with land cover, bordering countries and important rayons identified. The land cover categories were derived from GlobCover v 2.2, and reflect the final eight categories resulting from collapsing the 16 categories identified in Azerbaijan by the GlobCover surface.