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Ecological Niche Modeling of main reservoir hosts of zoonotic cutaneous leishmaniasis in Iran

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ABSTRACT

Zoonotic cutaneous leishmaniasis (ZCL), caused by *Leishmania major*, is a common zoonotic vector-borne disease in Iran. Close contact with infected reservoir hosts increases the probability of transmission of *Leishmania* parasite infections to susceptible humans. Four gerbil species (Rodentia: Gerbillidae) serve as the main reservoir hosts for ZCL in different endemic foci of Iran. These species include *Rhombomys opimus*, *Meriones libycus, Meriones hurrianae* and *Tatera indica;* while notable infection has been reported in *Nesokia indica* as well. The purpose of this study is to model the distribution of these reservoirs to identify the risk areas of ZCL. A data bank was developed including all published data during the period of 1970–2015. Maximum entropy model was used to find the most appropriate ecological niches for each species. The areas under curve obtained were 0.961, 0.927, 0.922, 0.997 and 0.899, instead of 1, for training test in *R. opimus*, *M. libycus*, *T. indica*, *M. hurrianae* and *N. indica,* respectively. The environmental variable with the highest gain when used in isolation was slope for *R. opimus* and *N. indica*, annual mean temperature for *M. libycus,* and seasonal precipitation for *T. indica* and *M. hurrianae*. Summation of presence probabilities for three main species, i.e., *R. opimus*, *M. libycus* and *T. indica* revealed favorable ecological niches in wide areas of 16 provinces. This is the first study to predict the distribution of ZCL reservoir hosts in Iran. Climatology and topography variables had high contributions toward the prediction of potential distribution of the main reservoir species; therefore, as climate changes, the models should be updated periodically with novel data, and the results should be used in disease-monitoring programs.

1. Introduction

Leishmaniasis is caused by different species of protozoan parasites belonging to genus, *Leishmania*. The etiologic agents of this parasitic disease are transmitted by the bite of a considerable number of sand fly species (WHO, 2010), and has diverse clinical manifestation including cutaneous (CL), visceral (VL) and mucocutaneous (MCL) forms. However, cutaneous form is the most common clinical syndrome (Bailey and Lockwood, 2007), and currently, the most important vector-borne disease in Iran (Shirzadi et al., 2015). It is a well-established fact that cutaneous leishmaniasis has long been identified in Iran. This is evident in Pollack's publication concerning the comprehensive description of cutaneous leishmaniasis in Iran, prior to the discovery of *Leishmania* parasite as the causative agent of the disease in 1856 CE (Nadim et al., 2008). Two types of cutaneous leishmaniasis, zoonotic cutaneous leishmaniasis (ZCL) and anthroponotic cutaneous leishmaniasis (ACL), are common in Iran. ZCL is regarded as a very important health issue and has endemic foci in rural areas of 17 out of 31 provinces (Yaghoobi-Ershadi, 2012). It is commonly associated with desert rodents, and transmitted to humans by sand flies vectors of *L. major* when they are in close contact with infected reservoir hosts, as a result of activities including agricultural practices, housing and residence in close proximity to active colonies of rodents (Nadim et al., 2008). There are two vectors for ZCL in

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Fig. 1. Iran and its neighbors.

Iran, *Phlebotomus papatasi* and *P. salehi* (Karimi et al., 2014). Ecological association and human tendency are two important criteria for vectors. On the other hand, vectorial competence of a sand fly vector will be complemented by frequent biting of reservoir and human hosts within an optimal ecotope (Ready, 2013). Therefore finding areas with high probability of presence for both vectors and reservoirs of ZCL will be beneficial to prevent human infection by planning relevant activities.

Previous studies have reported that gerbils (Rodentia: Gerbillidae) serve as main reservoir hosts of the etiological agents in different foci of ZCL in Iran, and the following species have been identified to be infected with *Leishmania major*, the causative agent of ZCL: *Rhombomys opimus*, *Meriones libycus, Meriones hurrianae* and *Tatera indica* (Yaghoobi-Ershadi et al., 2001; Mohebali et al., 2004; Rassi et al., 2008). This parasite has also been detected, in some studies, by PCR method in short-tailed bandicoot rat, *Nesokia indica* belonging to the Muridae family (Akhoundi et al., 2013).

Rhombomys opimus, the Great gerbil, is reported mainly in central and northeastern areas of Iran (Etemad, 1976), while in Southeast of Iran, subspecies of *Rhombomys opimus sargadensis* has been caught (Sedaghat and Salahi Moghadam, 2010). This species has been found to be infected by *L. major* in some foci of the country (Mohebali et al., 2004; Parvizi et al., 2008; Akhavan et al., 2010; Sedaghat and Salahi Moghadam, 2010; Bordbar and Parvizi, 2014; Mirzaei et al., 2014).

Meriones libycus, the Libyan jird, exists in low lying areas of the desert. It is reported in remarkable areas of Iran, mostly in eastern, southern and central provinces, but there are some reports from other susceptible areas too (Etemad, 1976; Yaghoobi-Ershadi et al., 2001; Yaghoobi-Ershadi et al., 2003; Rassi et al., 2006; Parvizi et al., 2008; Azizi et al., 2011; Amin et al., 2014; Azarpira et al., 2012; Bordbar and Parvizi, 2014; Nateghpour et al., 2015). In some foci of ZCL, such as Ardestan and Badrood counties of Esfahan Province, Neiriz of Fars province and endemic foci of Qom Province, libyan jird is the main reservoir and *L. major* was detected from some specimens (Sedaghat and Salahi Moghadam, 2010; Mirzaei et al., 2011; Rassi et al., 2011; Mirzaei et al., 2014).

The Indian Gerbil, *T. indica,* has been reported in south and south west of Iran (Etemad, 1976; Javadian et al., 1998; Hamzavi et al., 2000; Mohebali et al., 2004; Akhavan et al., 2007; Asgari et al., 2007; Yaghoobi-Ershadi et al., 2007; Sedaghat and Salahi Moghadam, 2010; Azizi et al., 2011; Kassiri et al., 2011; Yaghoobi-Ershadi et al., 2013). Studies conducted in the west of the country indicated that *T. indica* is the main reservoir of ZCL in the absence of *R. opimus* (Sedaghat and Salahi Moghadam, 2010). *Leishmania major* has been isolated from *T. indica* and characterized by microscopy and nested-PCR methods in suburban areas of Bushehr city, southwestern Iran (Yaghoobi-Ershadi et al., 2013).

Meriones hurrianae or Indian desert jird has been reported from a small area in southeast of Iran (Etemad, 1976; Azizi et al., 2011; Kassiri et al., 2011). It is considered as a ZCL reservoir in southeast of Iran (Sedaghat and Salahi Moghadam, 2010) and *L. major* has been isolated from this species following substantial characterization by microscopy, culture and RAPD-PCR methods (Mohebali et al., 2004; Azizi et al., 2011; Kassiri et al., 2013).

Nesokia indica, the short-tailed bandicoot rat, usually causes damage to crop in agricultural localities (Etemad, 1976). *Leishmania major* has been isolated from this species in some Middle East areas (Sedaghat and Salahi Moghadam, 2010). It has undoubtedly been identified in eastern, southern, central and western Iran (Etemad, 1976; Yaghoobi-Ershadi et al., 2001, 2003; Pourmohammadi et al., 2004; Akhavan et al., 2007; Asgari et al., 2007; Sedaghat and Salahi Moghadam, 2010). It has also been unveiled to be infected with *Leishmania* parasite in Khuzestan, Qom and Esfahan provinces, but *L. major* was only detectable by PCR method from a relatively fewer number of this species in Qom and Khuzestan provinces (Sedaghat and Salahi Moghadam, 2010; Akhoundi et al., 2013).

There are different approaches in modeling the geographical distribution of plants or animals. Using the ecological concept of niche, the set of biotic and abiotic environmental conditions in which that particular species can fit into without newly introduced subsidy (Holt and Gomulkiewicz, 1996), some models allow the identification of possible occurrence areas. Ecological niche models, in particular, are based on point occurrence data that have been gathered previously by other researchers, or obtained in the same study from field data collections. These models use digitized environmental layers and predict the spatial distribution of the study species (Peterson, 2008).

Therefore, incorporation of both ecological requirements and spatial locations of species occurring in an ecological niche model, results in the prediction of species occurrences in an area between the potential and actual distributions. With respect to leishmaniasis, several current studies exist for modeling the disease, its' vectors and reservoirs in some endemic areas (González et al., 2010; Gonzalez et al., 2014; Bray et al., 2014; Abedi-Astaneh et al., 2015; Hanafi-Bojd et al., 2015). Development of agricultural activities in different parts of Iran during the past three decades and change in land cover from uncultivated to crop fields, conduction of desertification control projects by planting tamarisk and haloxylon trees, the rapid development of urbanization and construction debris and waste disposal near residential areas, have provided appropriate places for nesting and breeding of rodent, providing close proximity to humans. These factors, along with increasing number of sand fly populations, have increased the risk of CL (WHO, 2010). This has led to the rise of annually reported cases of the disease exceeding 20,000 in recent years.