IOP Conference Series: Earth and Environmental Science

OPEN ACCESS

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To cite this article: Mengxu Gao *et al* 2014 *IOP Conf. Ser.: Earth Environ. Sci.* **17** 012265

Spatial distribution and ecological environment analysis of great gerbil in Xinjiang Plague epidemic foci based on remote sensing

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Abstract. *Yersinia pestis* (Plague bacterium) from great gerbil was isolated in 2005 in Xinjiang Dzungarian Basin, which confirmed the presence of the plague epidemic foci. This study analysed the spatial distribution and suitable habitat of great gerbil based on the monitoring data of great gerbil from Chinese Center for Disease Control and Prevention, as well as the ecological environment elements obtained from remote sensing products. The results showed that: (1) 88.5% (277/313) of great gerbil distributed in the area of elevation between 200 and 600 meters. (2) All the positive points located in the area with a slope of 0-3 degree, and the sunny tendency on aspect was not obvious. (3) All 313 positive points of great gerbil distributed in the area with an average annual temperature from 5 to 11 ℃, and 165 points with an average annual temperature from 7 to 9 ℃. (4) 72.8% (228/313) of great gerbil survived in the area with an annual precipitation of 120-200mm. (5) The positive points of great gerbil increased correspondingly with the increasing of NDVI value, but there is no positive point when NDVI is higher than 0.521, indicating the suitability of vegetation for great gerbil. This study explored a broad and important application for the monitoring and prevention of plague using remote sensing and geographic information system.

1. Introduction

As early as in 1924, the Central Asian desert great gerbil (*Rhombomys opimus*) plague natural foci was first discovered in Ake-Kamshe district in the north of Aral Sea，and the western of Xinjiang Uygur Autonomous Region (short for Xinjiang below) which located in the northwest of China and close to Kazakhstan belongs to the plague foci. Local plague preventing organizations have carried out many times of investigation on animal plague and five consecutive years survey of large-scale plague in Junggar Basin in 1950s, 1970s to 1980s, but never found the evidence of *Yersinia pestis in this area*. It's the first time to isolate 14 strains of *Yersinia pestis* form great gerbil and its parasitic fleas in Junggar Basin in 2005 [1, 2], it represented that the plague foci existed on bacteriology, which were identified the twelfth plague foci in China.

Plague natural foci usually has specific geographic ecological environment, and it is the ecological landscape unit with host, pathogen, media, environmental factors to produce animal epidemic outbreak of plague [3]. As the hosts of plague pathogen, animals with plague and their living environment usually have certain factors and basic conditions for plague foci existing [4]. The plague mainly exists in the area of certain type's rodents, and the latitude, altitude, slope, vegetation, and soil conditions are important influence factors on the distribution of the host animal. It's difficult to get the accurate distribution and division of plague foci in the past, however, the quickly development and widely application of remote sensing and spatial information technologies offer a good choice for that [3, 5]. Analysis of the habitats of main host animals and the different types of plague foci are necessary for effective application of the remote sensing technology [5, 6]. Adjemian selected the humidity, elevation, precipitation and other environmental variables to predict the distribution of 13 plague vector fleas in California, USA with the niche model [7]. Holt used rodent and human plague cases in 1984-2004 to predict the potential plague risk zone in 6 different climate scenarios model with the Maxent model [8].

Because the confirmation of the great gerbil plague foci is not long, and the shortage of related data, relevant research work on the spatial distribution of great gerbil plague foci with remote sensing and spatial correlation techniques are seldom in the past references. This study combined the monitoring data of great gerbil provided by Chinese Center for Disease Control and Prevention and other relevant ecological environment data obtained by remote sensing and spatial information technologies, carried out the quantitative analysis of the spatial distribution and the ecological environments of great gerbil plague foci in Xinjiang.

2. Data and methods

Using great gerbil data and ecological environmental variables derived from remote sensing technology, the overlay and statistical analysis were carried out for the distribution and ecological environment of great gerbil in the resolution of one kilometre in Xinjiang.

2.1. Great gerbil points data

Data of great gerbil was derived from plague surveillance provided by Chinese Center for Disease Control and Prevention (CDC). Great gerbil samples with a GPS position were obtained by active surveillance between 2008 and 2011 year by related organization of Xinjiang CDC. Then, all the great gerbil records were geo-located using GIS software, and a total of 313 unique locations were identified, excluding a record with incomplete position information. The distribution of great gerbil in Xinjiang was showed in figure 1.

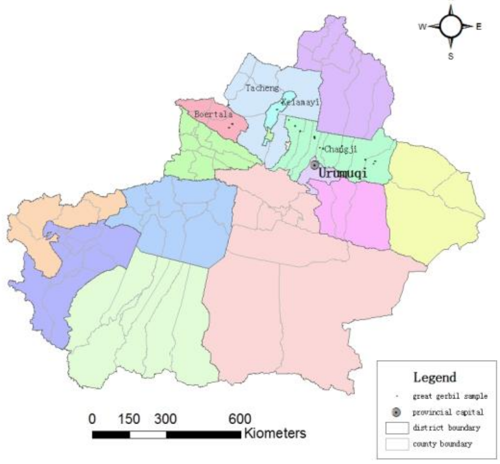

Figure 1. Geocoded data for great gerbil samples (313 unique locations) in Xinjiang

2.2. Data of ecological environmental variables
The research about the ecology of great gerbil showed that its distribution and density were related closely to local ecological environmental factors, such as temperature, precipitation, vegetation and soil [2]. Therefore suitable environmental parameters were selected from three sources, which affecting the distribution of the great gerbil including topographic data (elevation, slope, and aspect), annual temperature and precipitation in WorldClim data set, and NDVI from MODIS products.

2.2.1. Topographic data. The elevation, slope, and aspect were chose to describe the topographic situation. The elevation of the research area was resampled to a spatial resolution of one square kilometer from the SRTM data which resolution is 90 meters and can be downloaded freely. (http:// srtm.csi.cgiar.org/SELECTION/inputCoord.asp). Both slope and aspect variables were computed from the elevation of SRTM data using remote sensing software.

2.2.2. Annual temperature and precipitation data. These data were from WorldClim bioclimatic variable set which is a part of the Current WorldClim database representing the averaged data form 1950-2000 year. The data in WorldClim database which can be downloaded freely from the website (http://www.worldclim.org) were derived from monthly weather station measurements of altitude, temperature, rainfall and so on [8].

2.2.3. NDVI data. The Normalized Difference Vegetation Index (NDVI) can reflect the background (such as soil, snow, humid ground) effect of vegetation canopy, and correlate with vegetation cover. So, we chose the index data to represent the vegetation status. The data were from the composition product of NDVI 16days in the standard product MOD13A of MODIS. In our research, the NDVI data of Xinjiang in June 9, 2008 were mosaicked for further use.

2.3. Overlay and Statistical analysis
The data of great gerbil distribution and ecological environmental variables were transformed to a united resolution of one kilometre, and the elevation, temperature, precipitation and NDVI data were divided into different grades for further overlay analysis.

The elevation was divided into 6 grades including <0, 0-1000, 1001-2000, 2001-3000, 3001-4000, and >4000 (unit: meter) according to the local altitude situation. Then, the relationship between the distribution of great gerbil and the elevation were counted, and the area ratio of elevation with different grades was calculated. Furthermore, the elevation from 0 to 1000 metres were divided into 10 grades for detail statistical analysis

The slope and aspect were divided into 6 and 8 grades respectively, which were 0-3, 4-6, 7-9, 10-15, 16-25, and >25 for slope and 0-45, 46-90, 91-135, 136-180, 181-225, 226-270, 271-315, 316-360 for aspect with 0 representing due north direction, and both unit were degree. The annual temperature, precipitation and NDVI were divided into 8 grades with different value according to the great gerbil data. Finally, all the ecological environmental variables with different grades were carried out overlay and statistical analysis with the great gerbil data with the help of GIS software.

3. Result and analysis

3.1. The distribution analysis of great gerbil
As all the investigation records of great gerbil have located by GIS software, we calculated the distribution situation of all the 313 positive points by district/state of Xinjiang. We found that 191 points were in Changji autonomous prefecture with proportion of 61.02% in the whole points, and other points were in Kelamayi city, Tacheng district and Boertala autonomous prefecture. Furthermore, we counted the points distributed in different county and the result showed that each county in Changji have great gerbil records, representing the broad distribution state. But great gerbil points in Boertala only distributed in Jinghe county. The detailed statistical result in county level was showed in table 1.

Table 1. County distribution of great gerbil in Xinjiang.

ID	Districtic/ autonomous prefecture	County	Positive point number	Percentage (%)
1	Changji	Manasi	34	10.9
2	Changji	Hutubi	30	9.58
3	Changji	Jimusaer	30	9.58
4	Changji	Changji	22	7.03
5	Changji	Qitai	19	6.07
6	Changji	Fukang	19	6.07
7	Changji	Mulei	17	5.43
8	Changji	Miquan	20	6.39
9	Kelamayi	Kelamayi	48	15.3
10	Tacheng	Wusu	26	8.31
11	Tacheng	Toli	20	6.39
12	Boertala	Jinghe	28	8.95

3.2. Appropriate topographic analysis of great gerbil

Using the elevation of SRTM data, the overlay and statistical analysis were carried out by the elevation and the great gerbil distribution data. The result showed that all the 313 positive points distributed in the area with elevation of 0-1000 meters, which account for 29.7% of area in Xinjiang.

To analyse the appropriate altitude for great gerbil in the plague foci, the elevation among 0 and 1000 meters were divided into 10 grades using 100 meters distance and all the points located in each grade were counted. The statistical result was showed in table 2.

Table 2. Statistical analysis of great gerbil number and elevation in Xinjiang.

Grade	Elevation(m)	Positive point number	Percentage (%)	Cumulative percentage (%)
1	0-100	0	0	0
2	100−200	0	0	0
3	200−300	58	18.53	18.53
4	300-400	90	28.75	47.28
5	400-500	81	25.88	73.16
6	500-600	48	15.34	88.50
7	600-700	0	0	88.50
8	700-800	19	6.07	94.57
9	800-900	17	5.43	100
10	900-1000	0	0	100

The results showed that the positive point distribution of great gerbil was between 200-900 meters, excluding 600-700 meters. Without considering the sampling deviation, it can be considered that the suitable elevation of great gerbil is between 200-1000 meters, and elevation height at 200-600 meters is the most widely distributed and the percentage is 88.5%.

The overlay and statistical between slope and great gerbil points showed that all the positive point distributed in the slope of range among 0-3 degrees, representing the suitable slope state for great gerbil. The relationship between aspect and great gerbil points showed that there were more points in the north east, west and south west direction, indicating great gerbil tended to establish cave in warm and sunny place is not obvious.

3.3. Suitable annual temperature and precipitation analysis of great gerbil

To quantitatively analyse the relationship between the annual temperature and great gerbil distribution, we calculated the area percentage and great gerbil positive number in different annual temperature grades. The result indicated that most of the 313 great gerbil points belong to the annual temperature range of 5-11 degree centigrade, especially in the range of 7-9 degree centigrade, which area is about 11.1% of Xinjiang. The same calculation was carried out between annual precipitation and great gerbil distribution of the investigation point. The result showed that annual precipitation in most great gerbil points is belonging to 80-200 mm, especially in the annual precipitation of 160-200mm with area of 8.93% in Xinjiang.

3.4. NDVI and great gerbil analysis

The value of NDVI ranged from -1 to 1, and different value indicated different meaning. When the value is below 0, it represented the type of ground cover is cloud, water, snow and so on; When the value is equal to 0, the type of ground cover may be rock or bare soil; When the value is greater than 0, it indicated that there have vegetation, and the value is greater with increasing vegetation coverage. So the NDVI were divided into 8 grades according to many experiments, and the overlay and statistical analysis were carried out between the different NDVI value and great gerbil points. The statistical result was showed in figure 2.

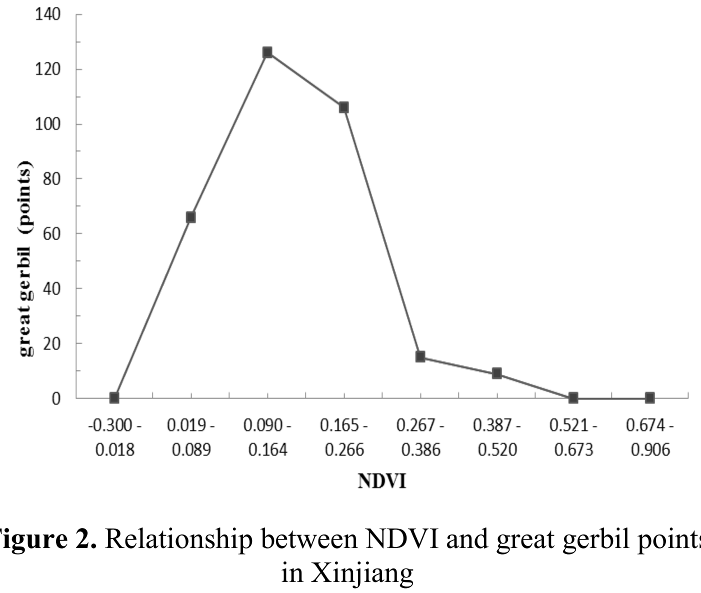

Figure 2. Relationship between NDVI and great gerbil points in Xinjiang

The statistical result showed the NDVI value is more close to the distribution of great gerbil, when the NDVI value increases, the positive points of great gerbil increases accordingly. But when the NDVI value reached 0.164, the positive points were up to the maximum and then the number reduced with NDIV increasing. When the NDVI value is higher than 0.521, there was no positive point.

4. Discussion and conclusion

As a main host animal in the foci, the distribution of great gerbil are significantly associated with the terrain, temperature, precipitation, vegetation and other ecological environment factors. Because most the ecological environment elements can be inverted and extracted quantitatively by remote sensing and other spatial information technologies, the spatial distribution and ecological environment of great gerbil can be analysed.

This study used the monitoring data of great gerbil provided by Chinese Center for Disease Control and Prevention and the ecological environment elements obtained from remote sensing and geographic information system to analyse the spatial distribution and suitable habitat of great gerbil in Xinjiang. The results showed that: (1) 88.5% (277/313) of great gerbil distributed in the area of elevation between 200 and 600 meters. (2) All the positive points located in the area with a slope of 0-3 degree, and the sunny tendency on aspect was not obvious. (3) All 313 positive points of great gerbil distributed in the area with an average annual temperature from 5 to 11 ℃, and 165 points with an average annual temperature from 7 to 9 ℃. (4) 72.8% (228/313) of great gerbil survived in the area with an annual precipitation of 120-200mm. (5) The positive points of great gerbil increased correspondingly with the increasing of NDVI value, but there is no positive point when NDVI is higher than 0.521, indicating the suitability of vegetation for great gerbil.

It showed that quantitative analysis of spatial distribution and appropriate ecological environment of great gerbil in a large scope were carried out successfully using remote sensing and geographic information system, exploring a broad and important application for the monitoring and prevention of plague. Futhermore, there're some uncertainties of the data sets used in this study, such as the great gerbil point data from the active surveillance, the environmental parameters retrieved from remote sensing and the climatic data from the WorldClim database, which are important for the accuracy of the results. These topics need to be discussed in the next step works.

Acknowledgments

This paper was supported by National Science & Technology Infrastructure Work Special Projects of China (Grant No: 2011FY110400, 2013FY114600); China Postdoctoral Science Foundation (Grant No: 2013M530708). Thanks to Chinese Center for Disease Control and Prevention (CDC) for providing the great gerbil point data.

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