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Spatial Distribution of Mosquitoes: Effects of the Water Supply and Drainage System in a Typical Metropolitan Area

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ABSTRACT

The relationship between the spatial pattern of mosquitoes and the water supply and drainage system at Zhujiajiao district Shanghai province, China, was studied by sample-plot and Pearson correlation analysis. The results showed that the TWINSPAN method sorted 61 sample in the study area into 5 types. The clustering results showed a strong correlation between landuse and population of mosquito. Correlation analysis showed that a significant negative correlation between the Aedes albopictus density and population constituent and perforated strainer, rainwater manhole covers, rain water covers, significant positive correlation existed between the Pale culex ones and perforated strainer, rainwater manhole covers, rain water covers. The Culex tritaeniorhynchus ones had the same trend as the Aedes albopictus. While significant correlation between the Anopheles sinensis and Culex tritaeniorhynchus, and significant negative correlation with sewage.

KEYWORDS Zhujiajiao Town; Mosquito; Microhabitat

Mosquitoes are a large group of organisms which affects the behavior of all living things, serving as a rich food source for insect predators, and stimulating the evolution of many defense mechanisms. Researchers have reported that the breeding locations, habitats, and behaviors of mosquitoes shift with the process of urbanization. As the population density of an urban area increases, the species, quantity, and spatial distribution of mosquitoes change Lu and Zhao, 2000 . The population size and spatial distribution of mosquitoes are affected by many factors, such as weather, human interference, and environmental factors. In order to reduce the effect of mosquitoes on human health, it is necessary to examine the relationship between the number and distribution of mosquitoes and relevant factors. Zhao, et al., 2009

In a rapid urbanization process, land use methods evolve and the environmental characteristics and mosquito community change, since mosquito breeding is closely associated with land use Shen, et al., 2012 . Researchers divide mosquito breeding locations into five categories: field and pond, slack stream, jungle, sewage, and container. Understanding of the classification of mosquitoes and the characteristics of mosquito breeding locations is critical to the investigation and prevention of mosquito-borne diseases.

Based on assumptions about the population characteristics and microhabitats of mosquitoes, this study performed sampling and analysis of mosquitoes in the Zhujiajiao area of Shanghai, land use types, and drainage systems, in order to explore the relationship between mosquito distribution and microhabitats in a typical metropolitan area. Determinants of mosquito distribution and characteristics are identified and analyzed, to provide support for future urban construction regulation.

1. Research Region and Research methods

1.1 Overview of Research Region

Located at the juncture of Shanghai Municipality and Jiangsu and Zhejiang provinces, Zhujiajiao town is bordered by Liantang Town, Songjiang Science and Technology Park, and Sheshan Town on the south, Dianshan Lake and Jinze Town on the west, and Dingshanhu Town, Kunshan City, and Jiangsu Province on the north. Lying on an important route to Jiangsu and Zhejiang,it has good transportation facilities and is well served by highways and a dense local road network.Its waterways include the Dianpu River, Lanlu Harbor, Xidaying Harbor, and the Zhumao River, all which can take vessels with100-500 tons burden, and is directly connected to the Huangpu River and Taihu Lake water systems. Including water areas, Zhujiajiao Town covers a total area of 138 km^2 (including water area), of which arable land occupies 2,110.84 hectares.

Fig.1 Location of sampling sites in Zhuajiajiao country, Shanghai, China

1.2 Research Method

This research examined the mosquito population characteristics in this typical metropolitan area via 61 sampling points in Zhujiajiao, Shanghai, from July 10, 2010 to July 11th, 2010. Samples were collected at 16:00 and 19:00 each day. The human induced method was adopted for sampling, and sampling continued for 1 h.

Research has shown that the home range of adult mosquitoes is 1-2km.In normal circumstances, they are mostly confined to that space, where they suck blood, rest, and lay eggs, seldom flying far away or migrating. In order to fully understand the relationship between mosquitoes and their microhabitats, this study focused on the relationship between the distribution of mosquitoes and their microhabitats. Each investigation point was defined as the center of a buffer zone of 0.5 km. Inside each of these zones, we collected statistics on land use type, rainwater well cover and sewer well cover of the buffer zone, and analyzed the relationships between mosquito distribution, land use type, rain water well cover, and sewer well cover.

UsingArcGIS9.3, buffer analysis and overlay analysis were adopted to perform a statistical analysis of the land use type, rainwater well cover, and rain grate and sewer well cover within 500 m of each sampling point. Quick Bird 0.6 m was used to collect the resolution data on land use type. Field measured data about rainwater well cover, rain grate and sewer well cover were collected. The population density was obtained by using the ArcGIS9.3 to analyze the regional population data collected by the Zhujiajiao Town government.

2. Results and Analysis

We collected a total of 516 mosquitoes belonging to 4 species: ***Aedes albopictus***, ***Culex pipiens pallens***, ***Culex tritaeniorhynchus*** and ***Anopheles sinensis***.

2.1Similarity Analysis of Mosquito Community at Different Sites

PC-ORD software was used to establish a distance matrix based on the important values of the 4 kinds of mosquitoes in the five habitats and 61 sampling points. The Euclidean Distance formula was selected. Ward's Method, a multi-element hierarchical clustering method, was used for clustering. Clustering results indicate that under the condition of retaining 75% of the information, the 61 sampling points may be roughly divided into five categories, and that the clustering of the sampling points effectively reflects the relationship between land use pattern and population density. The 5 categories found in the analysis include developed land with high population density, developed land with low population density, shrub land, grassland, and water bodies.

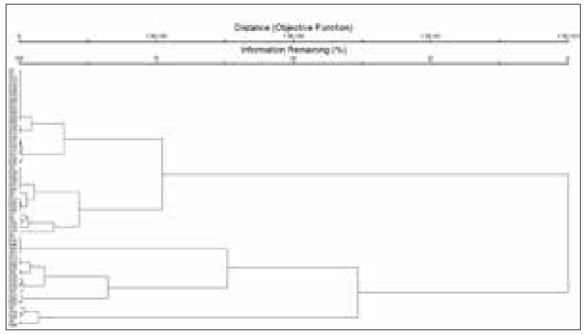

Fig.2 Dendrogram of 61 sampling sites, using group average linking of Bray-Curtis similarities calculated on fourth root of the transformed abundance data

2.2 Mosquito Community Correlation Analysis

The correlation analysis indicates that ***Aedes albopictushas*** a significant negative correlation with rain water well cover, rain grate, and sewer well cover, ***Culex pipiens pallens*** has significant positive correlation with rainwater well cover, rain grate, and sewer well cover, ***Culex tritaeniorhynchus*** has significant negative correlation with rainwater well cover, rain grate, and sewer well cover, and ***Anopheles sinensis*** is significantly associated with ***Culex tritaeniorhynchus***, but has a significant negative correlation with sewer well cover only.

Table1 Correlation matrix for the 7 characteristics of the Zhuajiajiao, Shanghai, China (Values are Pearson, *P<0.05, **P<0.01)

	Aedes albopictus	Culex pipiens pallens	Culex tritaeniorhynchus	Anopheles sinensis	rainwater well cover	rain grate	sewer well cover
Aedes albopictus	1.000						
Culex pipiens pallens	0.079	1.000					
Culex tritaeniorhynchus	-0.090	-0.019	1.000				
Anopheles sinensis	0.026	0.144	0.480**	1.000			
rainwater well cover	-0.295*	0.478**	-0.473**	-0.121	1.000		
rain grate	-0.346**	0.467**	-0.263*	-0.122	0.957**	1.000	
sewer well cover	-0.278*	0.595**	-0.457**	-0.420**	0.983**	0.964**	1.000

3. Discussion

In a large-scale space, the distribution of the mosquito population is affected by geographical location and climate characteristics (such as temperature, humidity, wind direction, and sunshine)Zhang et al., 2001; Zhao et al., 2009; Dai et al., 2011 .In a smaller space, the mosquito population density is subject to human disturbances such as drug spraying, environmental governance, clearance of breeding locations, and microhabitat differences (such as larvae breeding, and characteristics of local bodies of water)(Liu et al 2011; Gao et al, 2014a).

Mangaet et al.(1995) studied the airport area and Adak et al.(1994) found that changes in the ecological environment can lead to changes in mosquito population size. Shen et al.(2012) found that different land use methods can lead to differences in the number of mosquitoes, population density, and number of species in Wuxi and the same to results of this study, which suggested habitat had a great impact on mosquitoes.

In this study, the results of the cluster analysis divided the 61 sampling points into 5 categories. Field investigation and remote sensing imagery were then used to analyze the land use patterns. The analysis shows that the 5 habitats are directly correlated with the surrounding population density, landscaping, land development, and water areas. The number and species of mosquitoes studied in this paper are significantly smaller than in other studies, such as Zhao et al.(2009) in Beijing and Liu et al. (2011) in Qingyuan of Guangdong, and Gao et al. (2014b) in Shanghai. Bio has highly selective to environments and this results indicate that the area investigated is not conducive to the breeding of mosquitoes. This may be related to the short sampling period of this study. The results of the cluster analysis show that the mosquito distribution effectively distinguishes different land use types, especially developed land with high population density and developed land with low population density. This is probably because developed land is significantly different from other land types. Differences in population density on developed land lead to differences in green area (such as family flowerpots), water area (washbasin, toilets and other domestic water containers) and household garbage, resulting in differences in the breeding and growth of mosquitoes. A habitat different from other habitats, water areas are closely related to the breeding environment of mosquito larvae, since mosquito larvae can only complete their life cycle in water areas.

Similarity analysis indicates that, except for ***Culex pipiens pallens***, the distribution and quantity of rainwater well cover, rain grate, and sewage well cover are correlated with mosquito density. The drainage system has the largest impact, a negative correlation, on ***Culex tritaeniorhynchus***. ***Aedes albopictus*** is negatively correlated with rain grate and rainwater well cover. A large number of previous studies have shown that the characteristics of breeding locations and mosquitoes' high selectivity for ovi position sites are the main factors in the differences of mosquito populations across different regions and habitats (Vittor et al., 2006). ***Aedes albopictus*** primarily reproduce in standing water in artificial and plant containers, rain grates, and surrounding surface runoff that is close to the earth's surface, and is easily and quickly collected and retained, creating good artificial containers and breeding locations for ***Aedes albopictus***.

Though ***Culex pipiens pallens*** is positively correlated with the amount and distribution of rainwater well cover, rain grate, and sewer well cover, studies suggest that ***Cculex pipiens pallens*** breeds primarily in the contaminated water near human residencyes. The larvae can grow in contaminated water in crocks, pots, and other containers, but cannot breed in clean water in rooms. Important breeding locations of ***Cculex pipiens pallens*** include urban sewage ponds, drainage ditches, septic tanks, rainwater wells, sewer water, and fertilizer tanks for watering flowers and potholes on developed sites. Consistent with the results of cluster analysis in Figure 2, these samples are located near residential areas, with the highest population density and most frequent human activities. There residents plant flowers in their own courtyards, on balconies, and in other areas. Because of shortcomings in urban construction and planning, such areas have intensive rainwater well and sewage water well cover, where water accumulates in the bottom of wells instead of draining, resulting in ideal locations for the extensive breeding of ***Culex pipiens pallens***.

Culex tritaeniorhynchus is negatively correlated with rainwater well cover and sewer well cover. Its main breeding locations include paddy fields, clear sewage, still or semi-flowing water such as ponds, puddles, and marshes, container water, irrigation ditches, and other places that have sun, muddy bottoms, low water levels, and floating plants. Previous research has found that ***Cculex tritaeniorhynchus*** rarely breeds in urban areas. Li et al., (2007) first found the breeding of ***Culex tritaeniorhynchus*** in the water of a sewer well in downtown Beijing. They contended that there were two possible explanations for this. First, large-scale urbanization, demolition, and renovation in Beijing eliminated the original breeding locations of ***Culex tritaeniorhynchus***, and some ***Culex tritaeniorhynchus*** individuals had adapted to sewer environments in response. Second, Jin et al.(2012) argued that it could be that some ***Culex tritaeniorhynchus*** individuals had by chance entered the area and happened to survive. As the results of the cluster analysis (Figure 2) show, the distribution of ***Culex tritaeniorhynchus*** avoids developed urban areas with high population density, which have few aquatic plants such as rice. Meanwhile, on-site investigation found that large-scale open water areas lack aquatic plants and have good water quality, with a transparency of about 1 meter. Such areas are not conducive to the breeding of ***Culex tritaeniorhynchus*** larvae, thus further indicating that habitat can significantly affect the distribution of mosquito populations.

The population of ***Anopheles sinens*** is is significantly lower than the population of the other three kinds of mosquitoes, which may be an artifact of the relatively short sampling time. Previous studies indicate that ***Anopheles sinensis*** can be divided into two categories: domestic ***Anopheles sinensis*** and wild ***Anopheles sinensis***. A***nopheles sinensis***is active after dusk, and reaches its peak around midnight. They often perch in planted trees, reeds, and bushes during the day, or rest in barns. Some adult mosquitoes can survive the winter inside houses, livestock sheds, basements, air raid shelters, and animal caves. The larvae primarily live in water areas with aquatic plants such as rice.

Shen, et al., (2012) in a study of Wuxi, found that rural land has the highest mosquito density, and developed land has the lowest mosquito density, especially of ***Culextritaeniorhynchus***. The area investigated in this study contains no rural land to be developed, instead consisting entirely of developed urban land. The difference between our study and that of Shen, et al., (2012) lies in the microhabitats. Gao (2014b) explored Shanghai People's Park and People's Square, finding that mosquitoes are highly selective and adaptable to the environment, and that "suburban" mosquitoes gradually adapt to urbanized environments. In this study, mosquitoes in several habitats have completed the process of urbanization. Remote sensing and field surveys in the sample regions show hardened ground. The differences between the areas lie primarily in vegetation, number of residents, lifestyle, and their urban water supply and drainage network. In recent years, many construction projects have transformed the area, resulting in severe changes in the environment and habitats. The ecosystem has become unstable and reconstructed itself. Concurrent with this process, many artificial water bodies such as lakes and landscape water area shave been built in the city, giving mosquitoes increased breeding locations (She et al., 2008; Zhang et al., 2009). Thus, ***Culex pipiens pallens*** has gradually become the dominant mosquito species in parks and green spaces.

4. Conclusion

Though this paper identifies and analyzes the number, distribution, and population density of mosquito communities and local land use patterns, it does not perform an in-depth analysis. Future researchers should strengthen the study, thoroughly explore the relationship between microhabitats and mosquito distribution, and adopt field survey and remote sensing imagery for further analysis. The results of this study explore the relationship between mosquito population distribution and water supply and drainage systems. Combined with the results of previous research, we proposes that when designing urban drainage systems, planners should give full consideration to smooth drainage and the locations of rainwater well coverage, rain grates, and sewage well coverage, and adjust the external manifestations of the drainage system. This will enable better control of the mosquito population and mosquito-borne diseases.

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