Study on spatial-temporal distribution and environmental ties of Japanese B Encephalitis's mosquito vector as well as landing rate in The Olympic forest park

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Research

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Abstract

Background: Mosquito surveillance is crucial for understanding the epidemic potential, planning early-warning, and effective control strategies. As a key public place in Beijing, the Beijing Olympic Forest Park (BOFP) makes serious epidemiological means for the Beijing, and the survey on the Japanese B Encephalitis (JBE) vector of *Culex tritaeniorhynchus* and mosquito landing in BOFP is crucial for the people living as well as JBE surveillance and control. It was hypothesized that the *Cx. tritaeniorhynchus* could be trapped in a well-urbanization area of Beijing, and the distribution of *Cx. tritaeniorhynchus* and mosquito landing rate are determined by the environmental factors.

Methods: Thus, this investigation was performed to understand the spatial-temporal distribution of *Cx. Tritaeniorhynchus* and landing rate in BOFP, and the relationship between environmental features and densities of *Cx. tritaeniorhynchus* as well as mosquito landing rate, considering the vector competent of *Cx. tritaeniorhynchus* and important epidemiological means of BOFP in Beijing. From July to September, the *Cx. tritaeniorhynchus* was trapped with CDC-lights together with CO2 and the landing rate on the same sites as light traps were also investigated. What's more, the ties of environmental factors to the density of Cx. tritaeniorhynchus and landing rate was performed with SPSS, after the environmental factors datasets had been extracted with the 3S procedures.

Results: As result showed, the highest density of *Cx. tritaeniorhynchus* could be detected in September in the wetland environment, and the density was related to the grass-water in 400meters buffer (GW_400) and lower-trees in 100meter buffer distance (LT_100). For the landing rate investigation, the highest landing rates was observed in the wetland environment during September. In addition, there were two environmental features could be identified to correlate to landing rates; that is, grass-water in 400meters buffer (GW_400) and high-trees in 100meter buffer distance (HT_100). It was concluded that the *Cx. tritaeniorhynchus*, the vector of JBE, could be detected in BOFP (well-urbanization area), and the environmental factor could affect not only the spatial distribution of JBE vector but also the mosquito landing rates in BOFP.

Conclusions: The information achieved from this study could offer advice to people escaping from mosquito biting and provide useful information to prevent mosquito-borne diseases in Beijing, which means a lot to the public health of Beijing.

Introduction

Japanese B Encephalitis (JBE), one acute infectious disease transmitting through mosquito vector, pose a great risk to the health of people, special for the child[1]. The *Cx. tritaeniorhynchus* is the major mosquito vector in China, its population density is major factor influencing the JBE in a special area [2]. In China, the larva *Cx. tritaeniorhynchus* breeds majorly in a rice field and its' adult are always found in cattle shed[3], thus the *Cx. tritaeniorhynchus* is always considered as rural mosquito species. In recent years, however, the *Cx. tritaeniorhynchus* could be trapped in the urban area in China[4][5]. In the urban area of Beijing, the mosquito species that could be trapped generally include *Culex pipiens pallens* (vector for Bancroftian filariasis), *Aedes albopictus* (vector for Dengue fever). Therefore, the colonized of *Cx. tritaeniorhynchus* in the urban area of the city start to catch the focus from vector-epidemiology of view. The mosquito landing rates are an influential parameter to provide accurate correlations between human and mosquito contacts[6]. It not only indicates the mosquito density, but also predicts the potential of mosquito-borne diseases break-out, in the term of the mosquito-borne epidemiology [7]. Thus, landing rates investigation plays a key role in protecting people from mosquito attack and prevention of mosquito-borne diseases [8].

After the Olympic Games in 2008, the Beijing Olympic Forest Park(BOFP) transform from Olympic facility to an ecological parkland. Firstly, it improves Beijing's situation of environment and climate, for the reason that the BOFP is the important buffer barrier for Beijing urban ecological system. Specially, the BOFP is of great significance to maintaining the structure of Beijing urban ecological system (the continuity, bio-diversity protecting, preserve of species and its habitats) and even urban ecological security. Secondly, the Olympic forest park is opened to the public for free and becomes Beijing's most famous park for tourism, leisure, entertainment, sport fitness, etc. From public health point of view, the BOFP could also be one key point as surveillance of mosquito vector as well as its transmitting disease in the context of urban environmental system.

The vector population is closed correlated to the environmental factor[9, 10], which providing the breeding for larva and resting for adults[11–13]. So, studying the correlation of environmental factor with mosquito population could provide corresponded measures for the vector prevention and control. What’s more, investigating the landing rates under natural conditions, in various time scales and different environmental dimensions, can provide vital information for the guidance of mosquito control. Therefore, many studies have focused on mosquito landing rates, with regard to its temporal variation's characteristics[14, 15] and correlation with environment features [16, 17]. However, very few studies had described the trends of mosquito landing rates-being related to scales of spatial and time features, and there is no further research focusing on correlations between environmental features and mosquito abundance. Although some researchers had noticed the environmental influence on mosquito landing activity, they only focus on landing data on human, without further quantitative analyses on the association of environmental features to mosquito landing rates.

With the recent application advancement of 3S technology, especially RS-remote sensing and GIS-Geographic Information System, researchers are able to use these technologies for quantitative extraction of environmental features[11], conducting analyses of features with mosquito population indexes [18], and prevention of mosquito-borne disease[19]. That, the 3 s system had been used to study the correlation between environmental factor with malaria[20], dengue[21], WNV[22], and so on. Considering the advantage of the 3 s technology system, in this study, it was proceeding to study the correlation of the *Cx. tritaeniorhynchus* population density, mosquito landing rate, and environmental factors.

In present study, we took the BOFP as an experimental site to investigate the dynamic distribution patterns of JBE vector population, mosquito landing rates and ties to their surrounding environmental features. Taken the public health significance in accounted, studying here would benefit guarding against mosquito bites protection and mosquito-borne disease prevention, by the way of advising on escaping from mosquito biting for people as well as mosquito prevention for the BOFP. In addition, this paper could support on targeted ecological environmental reconstruction for mosquito prevention and prevent blindly ecological management with the vital significance of the ecological environment reserving in BOFP.

Material And Method

Study area

The Beijing Olympic forest park is the largest urban greening landscape in Asia, locating in of Chao-Yang district and covering an area of 680 hectares. The park is divided into south and north two gardens by fifth ring road of Beijing, and that two sub-parks are connected with one artificial simulation of the natural ecological corridor across city highway, which ensure the continuity of urban forest park ecological green space system and species diversity. This park, one of the important ecological barriers of Beijing, has important ecological strategic significance in quality improvement of urban environment and climate. Being one of the important public places of entertainment for people, studies on the spatial and temporal distribution of the mosquito vector in this area has important significance for reducing the crowd bitten probability and mosquito-borne diseases spreading probability.

GPS: Trapping sites' design and location

In the southern park, five areas were selected as experimental sites for measuring mosquito landing rates, including east (ease gate area with more trees), northeast (northern gate area of the forest besides the river), the wetland (western area with wetland), center island (center island surrounding by water) and south (south gate area with lawn). The coordinate information of five sites was provided with GPS using WV2 satellite remote sensing analyses.

RS: Surface features classification in BOFP

With remote sense packages in QGIS (QGIS.org (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org), the unsupervised ISODATA procedure was used to classify the surface features in BOFP basing on WV2 datasets. The surface features in BOFP could be identified as Residential Area(RA): human living environments, Open-Water(OW): water without any covering thing, High-Tree(HT): high trees like features, Low-Tree(LT): shrubs like vegetation, Grass-Water(GW): water with covering vegetation or well irrigating vegetation, and Lawn Area (LA): area covered with lawn area. What's more, the NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) raster datasets were also generated by remote sense analysis basing on WV2 satellite remote sensing data over the study area.

As the GW feature was found corelated to the vector density as well as landing rate, the field checking on the GW feature was then performed to identify the exact landscapes in BOFP. To do so, thirty randomly selected position in GW remote sense catalogic image firstly. Secondly, field checking exactly landscape type each of them basing on the spatial position information.

GIS: environmental spatial datasets surround trapping site

Different distance(100 m, 200 m, 400 m, 600 m, 800 m, 1000m)buffer area around trapping sites were produced in the context of geographic information system(QGIS.org (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org). Using the spatial analysis method, environmental data from each buffer area was extracted and listed at Table 1, and environmental classification database was built simultaneously.

Table 1.

The environmental features that would be used in this paper

Abbreviation of features	Geo-environmental sense
AC_100, AC_200, AC_400, AC_600, AC_800, AC_1000,	Artificial Construction's area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
OW_100, OW_200, OW_400, OW_600, OW_800, W_1000,	Open Water's area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
HT_100, HT_200, HT_400, HT_600, HT_800, HT_1000,	High Tree's area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
LP_100, LP_200, LP_400, LP_600, LP_800, LP_1000,	Low Plant's area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
GW_100, GW_200, GW_400, GW_600, GW_800, GW_1000,	Water with grass' area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
LA_100, LA_200, LA_400, LA_600, LA_800, LA_1000,	lawn area's area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
NDVI_100, NDVI_200, NDVI_400, NDVI_600, NDVI_800, NDVI_1000,	Total NDVI values within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
NDWI_100, NDWI_200, NDWI_400, NDWI_600, NDWI_800, NDWI_1000,	Total NDWI values within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.

1. Mosquito density survey with light trapping

The study period started from July to September, and trapping was performed twice in each month. The peak of local mosquito density lies in both July and August, so the CO_2-Trapping light was operated continuously during local mosquito density peak period. In these two months, trappings were done once every ten days period. The density of vector was calculated as counts/ (light hour), where the counts is the number of trapping vector, light is the number of light using for trapping, and the hour is the trapping time.

Mosquito landing investigation

The experiment of mosquito landing rates was initiated in July and ended in September. In each month, landing rates experiments were conducted twice a month, with one in the early of the month and the other nearly the end of the month. Each landing experiment lasted about fifteen minutes and was performed twice in one hour in which the mosquito biting peaks in Beijing. Randomly, five volunteers were chosen to perform the test at each site, and they were rotated in the following tests to avoid systematic errors, such as variations in mosquito attractiveness, density and site variation. Finally, the landing mosquito was caught and brought to the experimental room for morphological identification. The landing bite data was calculated as counts/(person·quarter), where the counts is the number of trapping mosquito, the person is the volunteer's number for trapping, and the quarter is the trapping time (fifteen minutes).

Statistical correlation analysis of mosquito's density with environments

Using SPSS19.0, regression analysis was performed to analyze the relationship of environmental variations with *Cx. tritaeniorhynchus* density and mosquito landing rate. According to the AIC value together with the P value, environmental factors relating to mosquito's density and landing rate were selected out and involved in regression analysis between the density and environmental features.

Results

The density of *Cx. tritaeniorhynchus* in each month of the total BOFP

The Fig. 2. shown the distribution of *Cx. tritaeniorhynchus* in each month in BOFP. During the trapping period, the density of vector mounted to the highest in September (11.2 mosquitoes per hour per light), and the density of the vector in July (0.35 mosquitoes per hour per light) and August (0.05 mosquitoes per hour per light) were smaller than 10 percent of that in September. As to predominance of *Cx. Tritaeniorhynchus*, it also arrived at the peak in September (26.92%), and the predominance of *Cx. tritaeniorhynchus* in July (2.81%) and August (1.12%) were not more than the five percent of total mosquito community.

The density of *Cx. tritaeniorhynchus* in each site

The Fig. 4 showed the vector density of each trapping site during each study month. There was no vector could be trapped in sites of east, northern-ease, center island, and southern in July and August; and only in September, the vector could be found in site east, northern-ease, center island, and southern. Both in July and August, the vector could only be trapped on site of wetland; and the density of the vector in September was the highest among all sites during each study month. Thus, the vector density and predominance spatial distribution pattern represented the same charters as that in total surveillance period. In the September, the Fig. 3 told us the density of the vector in each trapping position during the study period. The vector density in the wetland (13.58 mosquitoes per hour per light) was the highest among these trapping sites, and the vector density in east, northern-ease, and center island was 3.00 mosquitoes per hour per light, 4.25 mosquito per hour per light, and 10.00 mosquitoes per hour per light, respectively. Comparing to density distribution of *Cx. Tritaeniorhynchus*, the predominance of vector mosquito in trap sites displayed different distribution pattern, the center island ranks (72.73%) firstly among five sites following with north east (42.50%), east (29.27%) and wetland (16.15%), expect for the zero in south site (no vector could be detected here). Specially, the predominance of vector in wetland ranked bottom although its density lies on the top among trap sites.

Linear regression analysis of the density of the environmental factors

The factors, showing significant correlation level with vector density, was then involved into the linear regression model in the stepwise method, in which the factor entered the final model if the probability of F was smaller than 0.05 or was removed if the probability of F was larger than 0.05. In the end, the GW_400 and LT_100 was left and they could produce two linear regression models (Shown in Table 2). So, the finally linear regression model 2, as shown in Table 2, could be written in algebraic expression as:

Table 2
The relationship between environmental features vs mosquito vector density and landing rate

	Correlational environmental feature	Regression model		Coefficients	
		R Square	Sig.	Coefficients	Sig.
Landing Rate	GW_400	0.967	0.003**	2.816	0.003**
	HT_100			0.003	0.004**
Vector Density	GW_400	0.979	0.001**	1.535	0.001**
	LT_100			-0.004	0.016*
**: $P < 0.01$; *: $P < 0.05$					

Where the D is the density of *Cx. tritaeniorhynchus*, and the GW_400 and LT_100 are the summary acreage of grass-water and lower tress in 400 meters and 100meters buffer around the trapping sites, respectively. In the regression model, the GW_400($p = 0.001 < 0.01$), and LT_100($p = 0.016 < 0.05$) all showed significant linear relation with the density of *Cx. tritaeniorhynchus*, where the GW_400 was positive and the LT_100 was a negative linear relation to the density of *Cx. tritaeniorhynchus*.

Temporal dynamic of landing rates in different study positions in BOFP

During total survey period, landing rates in 5 sites display spatial diversity, with the landing rates climax in September at the site of wetland, east, and center-land; the bottom landing rates could be seen in July in north-east, south, and east, and the bottom landing rates also could be seen in August in wetland and center land(Fig. 4). In north-east gate of BOFP, the landing rates in August and September were higher than those in July. In the Wetland area, the landing rates reach its height in September and climax through in surveillance period among all trapping sites. In the south gate area, the landing rates is generally lower than the other position (the landing rates were no more than 4), even at the highest in August. In the East gate location, the landing rates grew step by step from July to September and peaked in September. In the center point area (one center island in the lake), the landing rates in August hit the bottom level through surveillance period.

Spatial dynamics of landing rates in each surveying month

From July to September, the landing rates in BOFP shown different distribution pattern among sites in different month. What's more, peak landing rates site came out from wetland in July and September, the bottom landing rates could be seen twice in the south in July and September(Fig. 4). In July, the landing rates range from high to low in the following rank: wetland, central island, north-east gate, east gate, and south gate (Fig. 4). In August, the landing rates is highest in east gate location, and the landing rates here was higher than the highest point of the landing rates in July (at the wetland site); the landing rates in Wetlands was lower than that in July, even lower than that in the northeast gate. Mosquito landing rates in five sites ranked from high to low in the following sequence: the east gate – northeast gate- wetland - south gate - Center Island (Fig. 4). In September, the landing rates, as that in July, peaked in wetlands again, and landing rates in this site were also peaked among all sites during the surveillance period. In addition, the landing rates in east gate site ranked second among all sites in September as well as in total surveillance period (Fig. 4).

The correlation of landing rates to environmental features in BOFP

The regression analysis results, on the relationship between environmental features and landing rates, was listed in Table 2. As the Table 2 shown, the P values of F testing on all regression models were less than 0.05, which means the models could well predict the landing rates with environmental features respectively. Moreover, it was noticed from Table 2 that there were alternative environmental features being identified correlation with mosquito landing rates. That, landing rates was positive correlation to GW_400(Coefficients = 2.816, P = 0.003 < 0.01), and landing rates was positive correlation to HT_100 (Coefficients = 0.003, P = 0.004 < 0.01). Also, the finally linear regression model, as shown in Table 2, could be written in algebraic expression as:

$$HLD=3.2+2.816*gw\_400+0.003*ht\_100$$

Where the HLD is the landing rate of mosquito, and the GW_400 and HT_100 are the summary acreage of grass-water and higher tress in the 400 meters and 100meters buffer around the trapping sites, respectively.

Field inspection on the GW environmental factors

As results are shown above, the GW was correlative to both the density of *Cx. Tritaeniorhynchus* and mosquito landing rate. In order to make ensures what exactly filed landscape the GW is, we also check 30 sites (Fig. 1) that was categorized as GW in RS analysis. As the results shown, these sites could be divided into four categories including well-irrigated grades (Fig. 5A, account for 43.33%), regularly irrigating flower shrubs (Fig. 5B, account for 40%), wetland covering with aquatic vegetation (Fig. 5C, account for 10%), and Turf with water (Fig. 5D, account for 6.67%).

Discussion

Temporal distribution of *Cx. Tritaeniorhynchus* and mosquito landing rate in BOFP

Throughout the survey period, mosquito species display diversity temporal pattern in the different environmental site[23–25]. In Shanghai, for example, Xue [26]tell us that there is one early spring peak in April and another peak during August and September. On the context of BOFP, which locates in well urbanization area of Beijing, both the density and predominance peak of *Cx. tritaeniorhynchus* could be seen in September, and there is only September peak. On the scale of Beijing city, September is not mosquito community density peak (should be in July or August). Thus, there is a temporal peak gap of density and landing rate between spatial scale of Beijing city and BOFP.

First of all, such peak departing my originate from spatial scale difference between Beijing city and BOFP, for the divergent climate or environmental factors. Second, the peak departing may also come from negative relationship between temperature and mosquito landing rates, as previous researches [27–29]. According to JBE surveillance in Beijing, the JBE case normally amounts to peak in late September[30]. From the viewpoint of mosquito-borne disease epidemiology, the coincidence of the vector density and landing rate in BOFP suggested that the risk of people in BOFP being bitted and infected with JVE must be biggest in September.

Spatial distribution of JBE vector and mosquito landing rate in BOFP

The spatial distribution of mosquito and landing rate is close related to the spatial position as well as the environmental feature around the positions [16, 17]. In this study, the density of mosquito vector and landing rate in wetland spatial rank first among five sites (Fig. 3 and Fig. 4). The water, together with plants breeding in it, is good condition for high-density breeding of mosquito larva[31]. Particularly, the *Cx. tritaeniorhynchus* is always bred in place that is water clear, slow flow, sunny hitting, and aquatic plants growing[3]. Here, the Wetland, with vegetation being ecological similar to typical breeding sites of *Cx. tritaeniorhynchus*, might be a responsibility to high-density *Cx. tritaeniorhynchus* in BOFP. Thus, high landing rates and mosquito vector density in a wetland accord well with mosquito ecology characters. On the contrary, with vegetation and water scarce, the southern gate site could only sustain for lower landing rates as well as mosquito breeding (the density of *Cx. tritaeniorhynchus* was zero through total period). Except for the southern site, the predominance of *Cx. tritaeniorhynchus* in wetland site was lower than those in other sites, which may result from the wetland is suited not only for the *Cx. tritaeniorhynchus* but also for other mosquito species. People, in different environment, needs diversity prevention and control measures to achieve the best control results [32–34]. After 2008, the BOFP gradually became key site of tourism, leisure, entertainment, sport fitness, etc. Hence, understanding the spatial distribution pattern of vector and landing rate in BOFP could contribute to better guide on the crowd protection from mosquito biting or potential JBE rise. What's more, the spatial distribution results also can help the park administer reducing the blindness of insecticide usage, unnecessary use of pesticide, pesticide residue, and damage to the environment.

Environmental factors tie to density of *Cx. tritaeniorhynchus* and mosquito landing rate

In general, the water body is an essential requirement for mosquito breeding, and the water with plantation (the water keeps good condition or weeds grow good environmental features) is the condition of the breed of mosquito with high larvae density[35, 36]. Also, it was demonstrated that the landing rates could be taken as important environment indication for mosquito breeding [37–39]. Therefore, both the landing rate and vector density were tied to the wetland in BOFP, and it also provide explain for the top density and landing rate in wetland sites, while the predominance in wetland rank end among five sites (except for the Sothern site). In BOFP, the wetland landscape provides good breeding condition not only for JBE vector but also for any other mosquito species. As to the low and high trees, it provide better rest site for adults mosquito[40], which may answer the question why the *Cx. tritaeniorhynchus* density was a positive correlation with these two environmental factors in the present paper.

In addition, this paper not only pointed out the exact factor which could affection on the landing rate and vector density, but also showed the exact distance by which the environmental factor could affect them. After the emergence stage, the adult mosquito flies from its breeding sites to the rest site, which was restricted by the spatial distance relating to the mosquito species, environment, and climates[41]. In addition, mosquitoes' influence on humankind or other host was restricted in limited distance buffer around its larva sites [42, 43]. Thus, the fly distance not only influences mosquitoes' harassment on humankind, but also lead to a diversity density, land rate, and infection rate of mosquito [44–46]. Identifying the buffer distance of environmental features affecting the landing rates illustrate the advantage of 3S technology on the analysis of environmental features with mosquito biting activity. Additionally, this study suggests a new point of view on mosquito behavioral science and contribute to decision on area extension of environmental management as well as chemical control.

Afforest irrigation might also be causes for high mosquito density in BOFP

As for field mosquito surveillance and environmental correlation analysis, the GW was tied to both the vector density and landing rate, and the density and landing rate in wetland (calculated as GW in remote sense analysis) rank first among study sites. Therefore, results here inform that the GW feature is key feature for the mosquito infestation in BOFP, and field checking on the GW feature in BOFP is necessary for mosquito and potential JBE risk management in BOFP. According to field checking, the GW feature in BOFP included four types: wetland with aquatic vegetation, well irrigated glades, regularly irrigating flower shrubs, and turf with water. For their stand water-body, the wetland with aquatic vegetation and turf with water are reasonably suitable for the mosquito breeding and corelated to the vector and landing rate.

While for the well-irrigated glades and frequently watered flower shrubs, their ties to vector density landing rate may due to their regular irrigation producing lots of micro-niche for the mosquito larva breeding and supporting for the rest of mosquito adults. Based on the results of this study, objective environmental management could be conducted, when relevant environmental features were considered to be dealt within the comprehensive control system of integrating mosquito management. First, caution message could be declared in a particular area (wetland, for example) where high-density and landing rate are high, advising on mosquito-prevent medical materials application. Second, people also could intermittent irrigation of water with aquatic plants grow in it, and reduce the flooding of trees, flowers and trees by lowering the risk of mosquito breeding or perch measures in order to decrease the landing rates on people Finally, we could do the breeding sites control or residual spraying over special environmental factor, in order to decrease the density of vector and landing rate at the same time.

Conclusion

The survey of JBE case in Beijing showed that some JBE cases were local people living in the well-urbanization area[47], which means that JBE transmits not only in the countryside but in the downtown area. li[5] and Zhou [4] also found the *Cx. tritaeniorhynchus* could be detected in the urban human-habiting area, but they didn't identify the breeding site of the *Cx. tritaeniorhynchus* and the environmental cause of the breeding in their paper. In present paper, however, the spatial-temporal distribution of vector and landing rate, and their ties to environmental features were identified by remote sensing and spatial analysis. From point of vector-borne disease epidemiology, the results obtained so far could provide some caution to us. First, the *Cx. tritaeniorhynchus* was found breeding in well urbanization area of Beijing, which might lead to an epidemic of JBE in the hot-spot area of this city. Second, urban afforest irrigation may also produce function mosquitoes breeding sites that lead to augmenting of vector density, which should be paid full attention. Third, as wetland could provide good eco-system for mosquito breeding, it is necessary to figure out effective ways to prevent the breeding of mosquitoes in this type of features. What's more, the wetland protection was looked as the best selection for ecological recovering in Beijing[48], thus, present paper would also warn that the risk of public health issue (*Cx. tritaeniorhynchus* and JBE, for example) also should be considered, during city wetland recovering proceed. Finally, present paper, regarding temporal dynamic of mosquito vector and landing rates, could assist residents on how to select the activity time and position in BOFP in order to reduce the biting or disease infection risk.

List Of Abbreviations

The abbreviations used in the text are listed as Table 1.

Table 1
The environmental features that would be used in this paper

Abbreviation of features	Geo-environmental sense
AC_100, AC_200, AC_400, AC_600, AC_800, AC_1000,	Artificial Construction’s area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
OW_100, OW_200, OW_400, OW_600, OW_800, W_1000,	Open Water’s area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
HT_100, HT_200, HT_400, HT_600, HT_800, HT_1000,	High Tree’s area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
LP_100, LP_200, LP_400, LP_600, LP_800, LP_1000,	Low Plant’s area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
GW_100, GW_200, GW_400, GW_600, GW_800, GW_1000,	Water with grass’ area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
LA_100, LA_200, LA_400, LA_600, LA_800, LA_1000,	lawn area’s area within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
NDVI_100, NDVI_200, NDVI_400, NDVI_600, NDVI_800, NDVI_1000,	Total NDVI values within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.
NDWI_100, NDWI_200, NDWI_400, NDWI_600, NDWI_800, NDWI_1000,	Total NDWI values within different buffer distance (100 m, 200 m, 400 m, 600 m, 800 m and 1000 m) around surveillance site.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

MEI-DE LIU and YONG ZHANG analyzed and interpreted the field data regarding mosquito and environmental features, and was the major contributor in writing the manuscript. YING TONG and HONG-JIANG ZHANG identified the mosquito caught in the BOFP and analyzed the field data of the mosquitoes. QIU-HONG Li, TING Liu, and XIAO-JIE Zhou performed the mosquito trapping and field landscape investigation. XIAO-PENG ZENG designed study, planed the field works, and directed the study procedures. All authors read and approved the final version of the manuscript.

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Figures

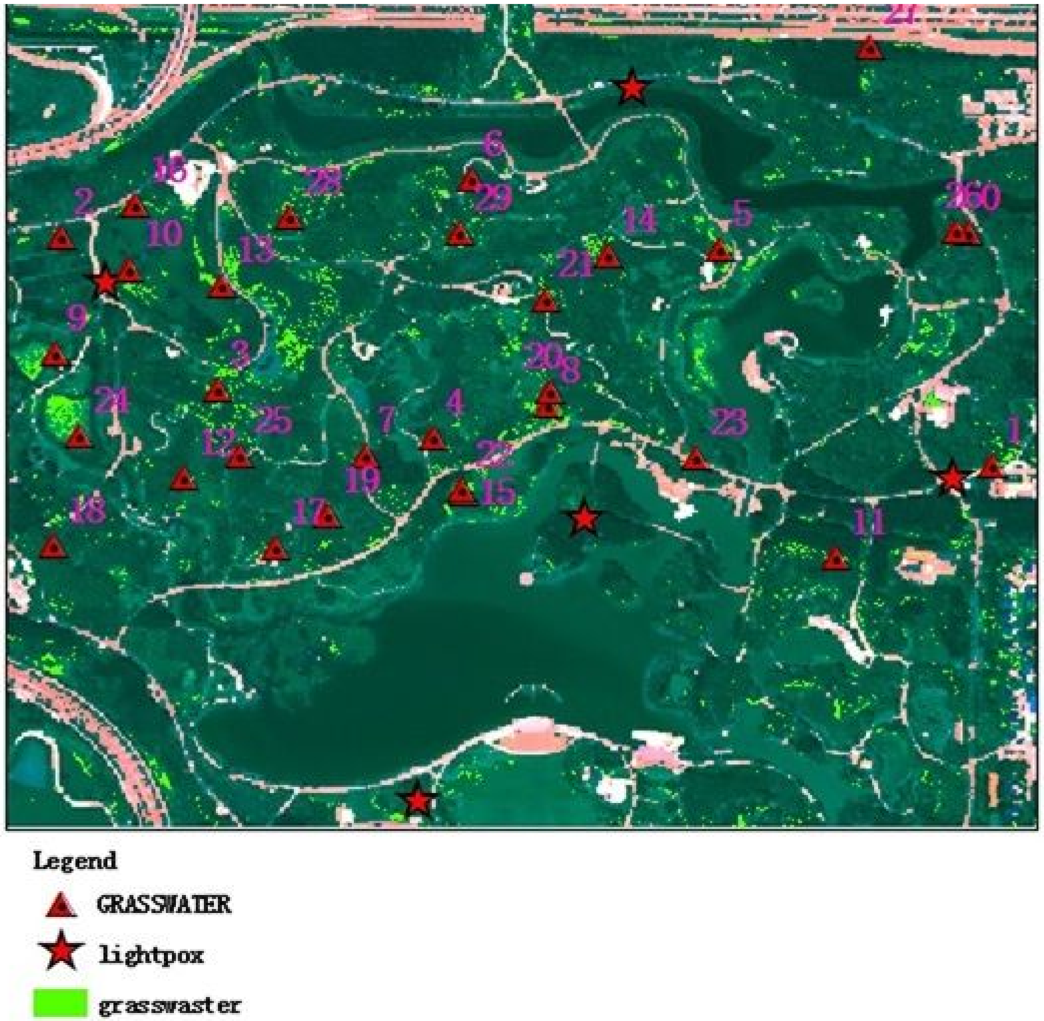


Figure 1

Map of trap sites and grass-water (GW) landscape in the study area.

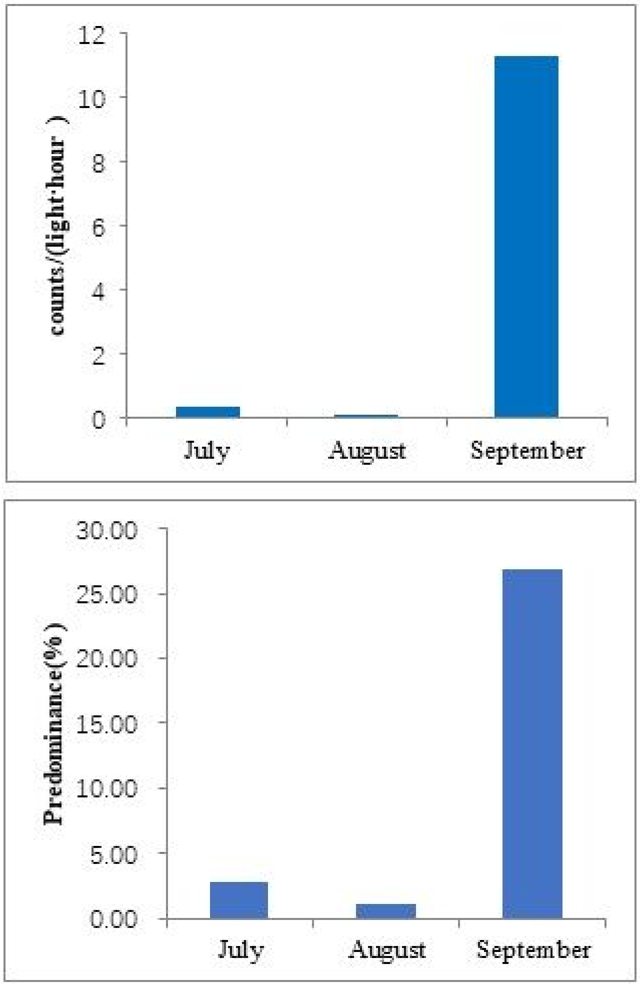


Figure 2

Density of Cx. tritaeniorhynchus in each month of the total BOFP.

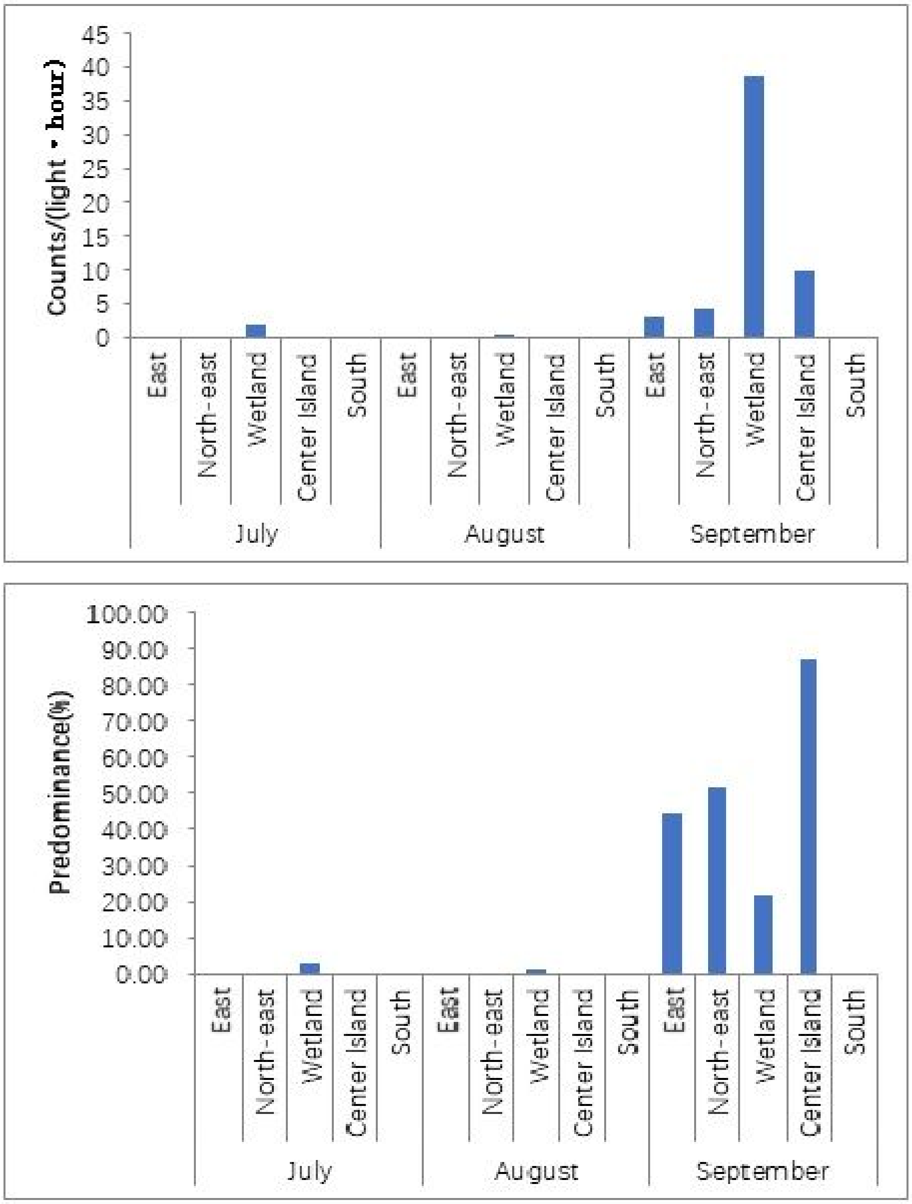


Figure 3

Density of Cx. tritaeniorhynchus at each site during three survey months (July, August, September).

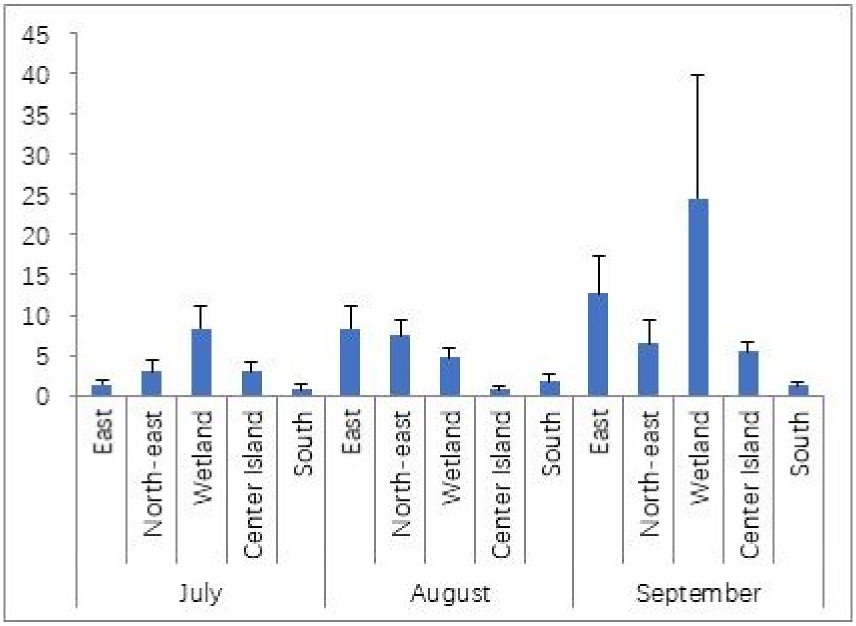
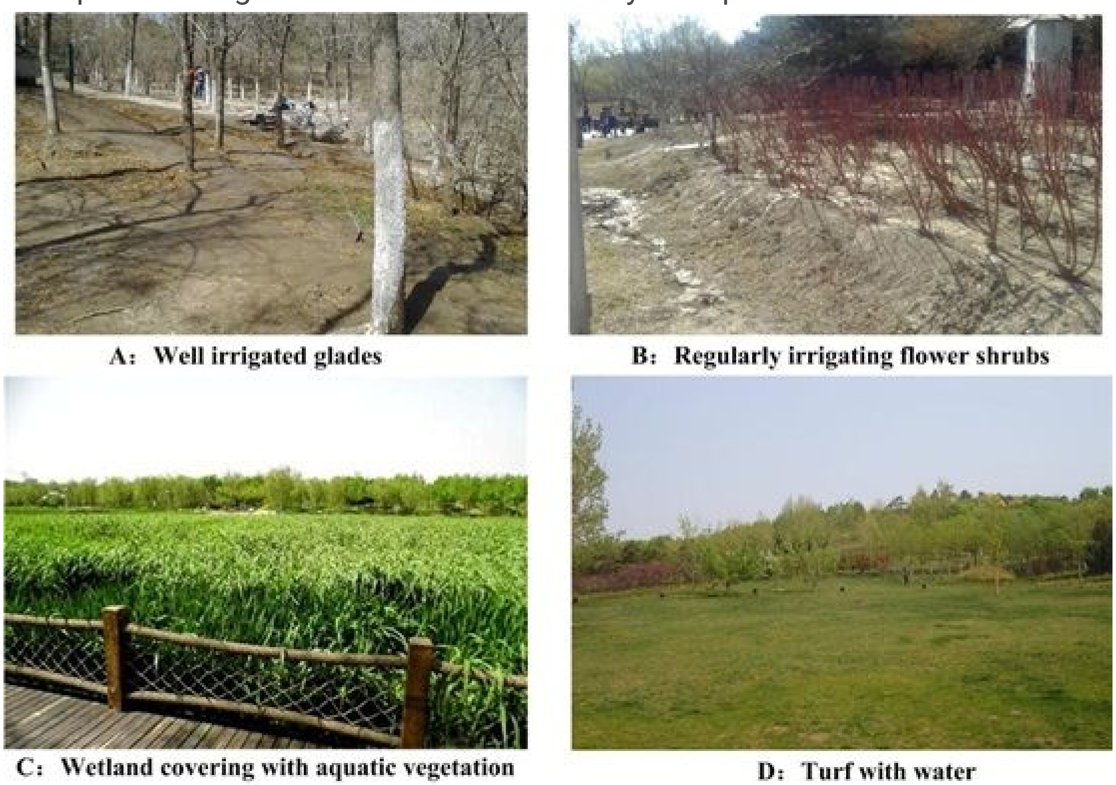


Figure 4

Mosquito landing rates at five sites from July to September.



A: Well irrigated glades

B: Regularly irrigating flower shrubs

C: Wetland covering with aquatic vegetation

D: Turf with water

Figure 5

The landscape of well-irrigated grades (A), regularly irrigating flower shrubs (B), wetland covering with aquatic vegetation (C) and Turf with water (D) in BOPF .