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Recommended Mosquito Risk Assessment Criteria for Urban Environment in London, UK - Targeting Mosquito-Borne Diseases

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Abstract: Factors such as climate change and world trade may lead to changes in the range of mosquitoes found in cities. Mosquito-borne diseases are one of the major public health problems worldwide (WHO, 2020). Thus, the risk of mosquitoes appearing in areas where people live is critical. The risk of mosquito have been devised in some countries, but they have mostly focused on assessing water bodies, ignoring the effects of other factors on mosquito survival.
This article presents the design of assessment criteria for urban environments based on three basic conditions for mosquito survival, i.e., saccharides, blood, and habitat. The criteria can be used in the assessment of environments in three general directions. The proposed assessment criteria were used in several sites in London to determine the reasonableness of the criteria and continuously improved.

Keywords: Urban environment; Mosquito risk assessment criteria

1. Introduction

Mosquitoes are carriers of many diseases such as dengue, malaria, yellow fever, etc., and are often found in areas where humans are active, posing numerous public health, economic, and social challenges. Mosquito-borne diseases cause more than 700,000 deaths globally each year, making them one of the major public health problems worldwide (WHO, 2020). At the same time, mosquito-borne diseases are spreading faster and mosquito ranges are beginning to change as a result of increased urbanisation and cross-border interactions such as global trade (Egid et al., 2023). In addition, changes in climatic conditions can also cause changes in mosquito life, due to the fact that mosquitoes are poikilothermal animal and their larvae are very dependent on temperature for hatching (Medlock and Leach, 2015). All the above phenomena are reminders of increased control of mosquitoes within survival environments, and some countries have devised their mosquito risk assessment criteria. However, these criteria are mostly directed to the assessment of water bodies, ignoring the fact that multiple scenarios in urban environments can provide conditions for mosquito survival. Therefore, it is important to design a mosquito risk assessment criteria for urban environments.

2. Methodology

The Methodology is divided into three main steps: identifying the basic components that could guide the assessment criteria, determining risk scores and levels, and using the assessment to assess mosquito risk in parts of London through fieldwork. The assessment

criteria may be improved again after the fieldwork has been carried out to identify shortcomings.

2.1 Identifying the components of the assessment criteria.

Three conditions need to be fulfilled for mosquitoes to reproduce: (i) saccharides, (ii) blood, and (iii) habitat. Identifying three general directions in which to use these three conditions as criteria for judging. The full assessment criteria are shown below and are based on a extensive literature review.

Table 1. Completed mosquito risk assessment criteria.

Consideration			Risk threshold	Risk rating
Saccharides	Plants		Growing plants with flowers	5
			Growing plants that bear fruit	3
			Planting only common green leafy plants that will not flower or bear fruit	1
	Artificial desserts		Artificial dessert waste in areas other than rubbish bins or landfill sites	2
			Only two or three artificial dessert wastes, which are negligible	1
Blood	Nature of the site		Public areas for entertainment and recreation (places where people gather)	3
			Private areas such as residential areas (low traffic)	1
Habitat	Water Body	Water depth	Less than 30 cm	7
			Between 30cm and 60cm	5
			Greater than 60cm	3
			Seasonal water body which dries out	1
		natural water cycle	Shapes of water bodies that are irregular and have multiple pinch points	2
			Simple shape of water bodies	1
		Plants	Gently sloping waterfront and have emergent plants in the water	3
			Gently sloping waterfront or have emergent plants in the water (only one of these conditions exists)	2
			Steep waterfront and there are no aquatic plants or only floating plants in the water.	1
		Water quality	Signs of eutrophication such as odour and algal blooms in the water column.	2
			The water behaves as clear and odourless	1
	Greenery	Grass height	Grass height over 5 inches (12.7cm)	5
			Grass height less than 5 inches	1
	Artificial Habitat	Roof	Have flat roofs	2
			Only have pitched roofs, no flat roof	1
		Artificial waste	Discarded or unattended water bottles, vases, old tyres, etc., in places other than bins, dumpsites, etc., which are regularly cleaned up	3
			Negligible presence of only two or three randomly discarded man-made wastes	1

2.1.1 Saccharides

Sugars required by mosquitoes come from plants as well as artificial desserts. The nectar in plants will provide mosquitoes with amino acids, proteins, antioxidants, vitamins, lipids, and many other ingredients (Kevan and Baker, 1983). Damaged, fermented or rotting fruits will also become food for wild mosquitoes (Joseph, 1970; Thebald, 1901). For adult phytophagous mosquitoes, nectar is the most important and utilised part of their diet compared to other parts of the plant (Foster, 1995; Stone & Foster, 2013; Nyasembe & Torto, 2014). Therefore, mosquito risk was highest in the presence of flowering plants, followed by fruiting plants, and lowest in flowerless and fruitless plants.

In urban areas where waste is not collected and disposed of in a timely manner and rainfall is frequent, mosquito communities can be severely affected by sweetened waste and will have epidemiological implications (Dieng et al., 2017). However, only few studies have demonstrated that desserts can be a food source for mosquitoes, and therefore artificial desserts have a lower maximum mosquito risk score compared to plant-based sugars.

2.1.2 Blood

The blood will provide the mosquito with essential nutrients such as cholesterol and amino acids. Mosquitoes have a variety of hosts, but humans may be their preferred choice, as

Scott et al. (1993, 2000) mentioned that Aedes aegypti preferred to feed on human blood in the presence of dogs, pigs, cows, and other animals as a food source. On public lands with recreational functions, human traffic is generally higher and mosquito risk is consequently higher. On the other hand, in private land, such as residential areas, there is less human traffic and the mosquito risk is lower.

2.1.3 Natural habitat

For mosquitoes, their natural habitat includes water bodies as well as green spaces. The depth, shape, aquatic vegetation, and water quality of a water body will affect the survival of mosquitoes.

There is a relationship between water depth and oxygen concentration, so water depth will greatly affect the survival of mosquitoes. There is a possibility of expansion of mosquito population in water depth less than 30cm (Lindasy, 2013). In wetlands where the water depth is more than 30cm, the emergent plants will be replaced by floating plants due to their poor state of health, leading to an increase in mosquitoes (Knight et al., 2003). Lindasy (2013) claimed that water depths of more than 60cm will make the water environment less supportive for the survival of mosquitoes. Whereas seasonally dry water bodies do not provide a stable environment and therefore mosquito risk is lowest.

The shape of the water body will affect the natural water circulation, which carries on determining whether mosquito eggs can stay in place. In addition, simple shapes of water bodies will promote water circulation thus improving water quality, in addition to providing mosquitoes with less space to hide from predators and reducing mosquito breeding (R Byun, 2012). Simple shape water body is smaller mosquito risk, vice versa is higher.

The vegetation in and around the water body will directly affect the survival of mosquitoes. The slope of the edge of the water body will directly affect the growth of plants at the water's edge. R Byun (2012) mentions that on steep water banks, the growing width of large plants will be limited, thus reducing the shelter for mosquito larvae. Whereas for aquatic plants, emergent plants are more favourable for mosquitoes compared to floating plants (Yadav et al., 2012).

In eutrophic (i.e. poor water quality) water bodies, the richness of organic matter and microorganisms will provide a food source for mosquito larvae. In addition, in eutrophic water bodies, predators preferentially feed on smaller prey reducing the threat to mosquito larvae (Quiroz-Martínez and Rodríguez-Castro, 2007). In the case of poor water quality in water bodies, mosquito risk is high, vice versa is low.

In addition to water bodies, green space vegetation can also provide habitat for mosquitoes. Heritage Pest Control (2023) mentions that cutting grass as short as 5 inches in length is an effective way to prevent mosquitoes from congregating. Therefore mosquito risk is lower when the lawn height around the environment is less than 5 inches.

2.1.4 Artificial habitat

In urban environments, mosquito habitats will contain all containers where water can be stored, such as building roofs, urban waste, etc.

Roofs with less slope are more likely to form temporary bodies of water after rain, providing an environment for mosquitoes to survive.Rinawan et al. (2015) through their study found that dengue fever is more likely to be present on roofs with less slope. Thus mosquito risk is higher in presence of flat roofs, vice versa is low.

Discarded vases, water bottles, and old tyres in urban environments can be a place for mosquitoes to live.Wilke et al. (2019) demonstrated through their study that in urban

environments in Miami-Dade County, mosquitoes may survive and reproduce in any object that can hold water, such as deflated basketballs as well as water scooters or storm drains can be their habitat. Mosquito risk is higher in environments with more artificial waste.

2.2 Determine level of risk for mosquito breeding potential

After the field visit, a judgement on the riskiness of mosquito invasion was required based on the total score. The minimum score for the total score was 10 and the maximum score was 34. The risk potential was categorised into three levels, corresponding to score bands of 10-17, 18-26 and 27-34.

Table 2. Level of mosquito risk

Risk potential	Total score	Description
Low	10-17	There is a very small chance of a mosquito invasion in the future
Medium	18-26	There is some possibility of a mosquito invasion in the future
High	27-34	There is a high probability of a mosquito invasion in the future

3. Results and discussion

In order to study the riskiness of mosquito invasion and settlement in the London area, selected areas located in London were assessed and scored given. Other factors affecting mosquito risk may be identified after the fieldwork and will be added in order to improve the existing assessment criteria.

3.1 Location 1: UCL campus and Wharf Road Gardens

The reliability and usability of the assessment criteria needed to be verified before they could be formally used. WWT London Wetland Centre, which is infested with mosquitoes, and UCL campus, which is mosquito-free, were chosen as the two sites for assessment. WWT London Wetland Centre (2014) mentioned the presence of mosquitoes in the wetland. After the assessment, WWT London Wetland Centre scored 24 with a risk level of medium and UCL campus scored 13 with a risk level of low. This proves that the assessment criteria is reasonable.

3.2 Location 2: Wharf Road Gardens and part of the surrounding streets

During this fieldwork it was found that on the Espérance Bridge, although there is a high flow of people, it only serves to connect the two sides of the river and people rarely stay. However, people's state of activity often affects the mosquito's blood-sucking process, as Martin- Martin et al. (2023) mentioned that mosquitoes need to suck blood before the host disturbs or kills them, otherwise it will affect the absorption of the blood and affect the laying of eggs. It has been found that spaces designed for socialising will attract people to stay, with spaces that provide a variety of activities and features that allow for social interaction (Mehta, 2013). For spaces that provide usable lawns, well-maintained walkways, seating, and commercial facilities, i.e., user-centred spaces, they often attract people to stay (Chen et al., 2016). The mosquito risk is higher when there are designs within the venue that attract people to stay. This consideration should be added to the previous assessment criteria.

3.3 Location 3: Brunswick square and part of the surrounding streets

Two field trips to the region were conducted on different dates and the results from the two trips were somewhat different, as shown in the figure below.

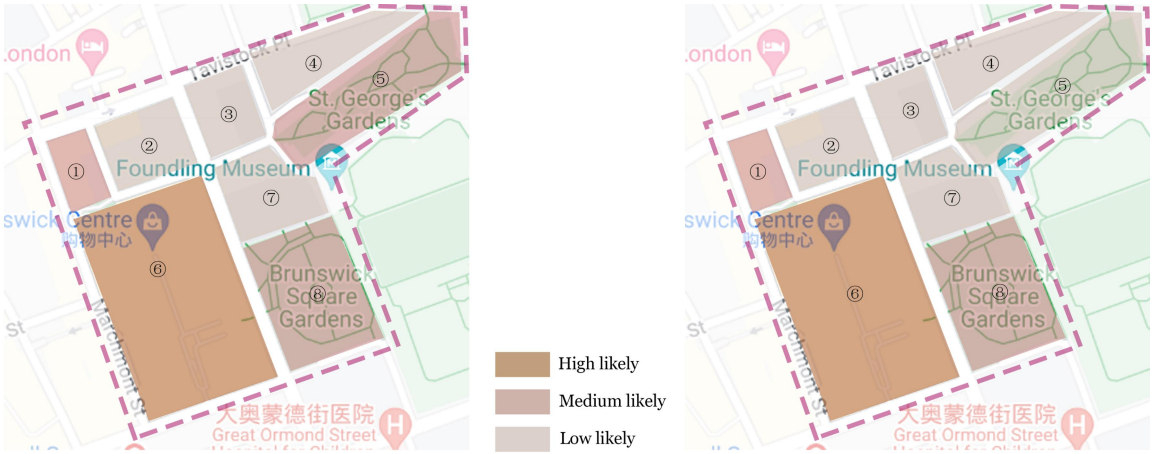

Figure 1. Risk map of Brunswick square and surrounding streets

The differences were mainly in the scores of the three considerations: plants, artificial desserts and artificial waste. In the first visit, which was conducted on a weekend, there was a lot of artificial waste and flowering plants in the site due to the high flow of people and the lack of cleaning staff. However, on the second visit, which was conducted on a weekday, there was significantly less artificial waste and the flowering plants disappeared (withered). Therefore the above three considerations should be modified. When scoring the consideration of plants, not only the actual flowering and fruiting status of the plants at the time of the field trip should be taken into account, but also the effect of the flowering cycle of the plants grown on the site on mosquito reproduction. The consideration of artificial desserts and artificial waste should be evaluated in terms of the ability of the waste to remain on the site for long periods of time.

4. Conclusion

Although the study identified some flaws in the mosquito risk assessment criteria after several field visits and corrected them, there are still some limitations.Firstly, different species of mosquitoes have their own preferred habitats and hosts, and their adaptive abilities are also different. Therefore, designing different assessment criteria for different species of mosquitoes may be more targeted and can improve the accuracy of the assessment.

In addition, this study focuses on urban environments, and future research could design mosquito risk assessment criteria for suburban or rural areas, where the degree of greenery and population concentration may vary, and thus the likelihood of mosquito invasion may also vary.

In addition to the points mentioned above, the assessment criteria may serve as a reference for urban planners in the future design process to help cities reduce the likelihood of mosquito invasion and spread. For example, a mosquito risk assessment of an existing wetland. If the risk level is found to be high, some planning measures need to be taken, such as setting up wetland isolation zones or keeping a certain distance from the wetland when new residential areas are built.

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