Landscape and Urban Planning 162 (2017) 115–125

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Mosquito assemblages associated with urban water bodies; implications for pest and public health threats

William Crocker[a,*], Kim Maute[a], Cameron Webb[b,c], Kris French[a]

[a] Centre for Sustainable Ecosystem Solutions, School of Biological Sciences, University of Wollongong, Wollongong, NSW 2522, Australia
[b] Marie Bashir Institute of Infectious Diseases and Biosecurity, University of Sydney, Sydney, NSW 2006, Australia
[c] Department of Medical Entomology, NSW Health Pathology, Westmead Hospital, Westmead, NSW 2145, Australia

HIGHLIGHTS

- Mosquito diversity and abundance varied significantly across the metropolitan area.
- Estuarine areas contained the highest abundance of mosquitoes and unique species.
- Mosquito abundance and diversity changed less at urban and suburban sites.
- Findings highlight the importance of monitoring high-risk coastal urban areas.

ARTICLE INFO

Article history:
Received 23 June 2016
Received in revised form 8 February 2017
Accepted 10 February 2017

Keywords:
Urban
Mosquito
Mosquito-borne disease
Stratford virus
Community structure
Coastal

ABSTRACT

Mosquitoes and mosquito-borne pathogens within urban regions may vary in response to short-term spatial and temporal changes in climate, as well as the distribution of water bodies, habitats and wildlife. Predicting where and when mosquito-borne pathogens are likely to occur is vital to safeguarding against outbreaks of human disease and developing strategic mosquito management programs. The aims of our study were to determine: 1) the spatial and temporal variability in mosquito communities over the late summer and early autumn in a metropolitan region; and, 2) the presence of arboviruses in the various mosquito species at the sites and the implications for mosquito-borne disease risk. Mosquito populations were sampled, and tested for the presence of arboviruses, using a replicated CO2 trap sampling design to determine the spatial and temporal variability in mosquito communities over the late summer and early autumn in the metropolitan region of Sydney, Australia. Eleven sites were classified as highly urban, suburban or estuarine, based on the water habitats present and distance from the central business district. Mosquito community composition within metropolitan urban regions was not significantly different from those in suburban areas with nearby bushland. However, areas associated with estuarine wetlands recorded significantly different mosquito fauna and a higher abundance of mosquitoes. Stratford virus was the only arbovirus detected in the study and was detected at a higher incidence at the three estuarine sites. This mosquito-borne pathogen is considered of only minor public health concern and while more hazardous viruses were not detected, the high abundance of known vector mosquito species highlights the potential risk and suggests the need for annual surveillance to assist local health authorities mange these risks. Our findings highlight the importance of considering estuarine areas separately when assessing the risk of mosquito-borne disease. This is critical for many cities globally, as important population centres are often located in coastal areas adjacent to estuarine wetlands.

1. Introduction

Urban regions can support a diverse range of mosquito species, reflecting the multitude of potential habitats associated with permanent and ephemeral water bodies. Some of these mosquitoes are known to be efficient vectors for a variety of human and animal pathogens, while others pose little human health risk (Webb, Doggett & Russell, 2016). The assemblage of mosquito species present influences the potential activity of mosquito-borne pathogens (Steiger, Johnson, Hilbert, Ritchie, Jones & Laurance, 2012) so understanding the site-specific roles of urban water bodies

* Corresponding author.
E-mail address: williamcrocker92@gmail.com (W. Crocker).

http://dx.doi.org/10.1016/j.landurbplan.2017.02.006
0169-2046/

and their associated mosquito communities is critical in assessments of public health risks.

Despite high levels of residential, recreational and industrial development, major urban regions such as Sydney, Australia, have an abundance of diverse habitats that may be suited to mosquitoes. These habitats mainly include small temporary water bodies, permanent freshwater vegetated lakes and ponds and estuarine coastal waterways. As a result of this habitat diversity, over 60 different mosquito species have previously been recorded from the region (Webb, Doggett, Willems, Russell, Clancy & Geary, 2001).

An understanding of the mosquito species community, abundance and temporal change associated with each habitat can assist managers in the management of pest and public health risks. The pest and public health risks associated with mosquitoes found in major metropolitan regions will vary with the abundance and diversity of locally significant habitats, environmental and climatic factors and locally significant mosquitoes. In warm temperate or tropical coastal cities in Australia, the United States of America, Africa and Asia, distance from mosquito habitat has been correlated with increased incidence of mosquito-borne disease (Hu, Mengersen, Dale & Tong, 2010; Midega et al., 2012; Haque, Huda, Hossain, Ahmed, Moniruzzaman & Haque, 2009; Nolan, Zangeneh, Khuwaja, Martinez, Rossman, Cardenas & Murray 2012; Jardine, Neville & Michael, 2015). While some mosquito species prefer permanent, vegetated freshwater habitats like lakes and ponds (Webb, 2013), others are adapted to small, temporary water bodies like containers, drains and puddles (Montgomery & Ritchie, 2002; Armistead, Nishimura, Arias, & Lounibos, 2012). Estuarine species take advantage of brackish and estuarine wetlands (e.g. salt-marsh, mangroves and coastal swamp forests) that are too saline for other mosquitoes to survive (Roberts, 1996). The dispersal of adult mosquitoes from their larval habitats varies greatly with species (Blaustein, 2004; Russell et al., 2005; Watson, Saul & Kay, 2000), however, some mosquitoes, particularly those associated with estuarine wetlands, can disperse widely from local habitats and influence pest and public health risks many kilometres from wetland habitats (Jardine et al., 2015).

Estuarine sites have historically, and currently, been targeted for mosquito control because of the high abundance of vector species found in mangrove or salt-marsh habitats (Russell & Kay, 2008). However, the overall risk these habitats pose is likely to vary not only in response to mosquito species presence, abundance and the proximity of breeding sites to the human population, but will also depend on the level of recreational activity (Magy, 1968; Vanwambeke, Bennett, & Kapan, 2011) and wildlife abundance and diversity (Hill, Power & Deane, 2009) that represent potential reservoirs of mosquito-borne pathogens.

Mosquito populations change in response to temporal variation in weather conditions such as temperature and rainfall (Chuang, 2011; Walsh, Glass, Lesser, & Curriero, 2008; Medlock, Avenell, Barrass, & Leach, 2006; Micieli & Campos, 2003). Therefore, mosquito influence on public health is not static (Denlinger & Armbruster, 2014; Webb, 2013). For cities where disease risk is spasmodic, the possibility of outbreaks of significant human diseases is likely to vary from month to month and year to year in response to changes in mosquito abundance and infection of the disease within mosquito populations. Sydney, like many cities in temperate regions, still suffers occasional outbreaks of mosquito-borne disease due to an abundance of suitable zoonotic reservoirs of mosquito-borne pathogens (Newman Stirzaker, Knuckley, Robinson, & Hood, 2008; Amin, Hueston, Dwyer & Capon, 1998). The Sydney metropolitan area retains large areas of parkland as well as natural and constructed waterways, and is home to over 100 terrestrial mammal species (Recher 2009) and approximately 140 bird species. This is likely to be influenced by the construction and rehabilitation of urban wetlands which influence the abundance and diversity of not only of mosquitoes, but also local wildlife.

The mosquito-borne pathogens of greatest concern to human and animal health in major urban centres of Australia are viruses of the *Alphavirus* and *Flavivirus* genera, such as Ross River virus (RRV), Barmah Forest virus (BFV) and West Nile virus (Kunjin subtype) (WNV_{KUN}) (Thompson et al., 2015; Russell & Dwyer, 2000; van den Hurk et al., 2014). Mosquitoes present in the region are also known to transmit other flaviviruses, such as Edge Hill virus (EHV) and Stratford virus (STRV) which are thought to cause mild illness in humans (Heinz et al., 2000; Nisbet et al., 2005). However, the public health risks posed by these pathogens are not well understood. By determining the spatial and temporal variation in mosquitoes, we can better assess the public health risk of mosquitoes (van den Hurk, Hall-Mendelin, Johansen, Warrilow, & Ritchie, 2012; van Uitregt, Hurst & Wilson, 2013).

A number of focused surveys have been conducted within Sydney as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program and over 60 species of mosquitoes were known from the local region. However, these previous investigations have not sampled mosquito populations across such a wide geographic region at a similar time point to confirm that coastal estuarine habitats harbour significantly more mosquito abundance and diversity. Australia is generally free of day-only active mosquitoes. Some mosquito species will be active during the day in addition to the early evening and night so will still be collected in normal sampling. The mosquito species that are primarily active only during the day, especially *Aedes aegypti*, are generally limited in their distribution to northern regions of the country (Webb et al., 2016). Given our current knowledge of the mosquito communities and the need to predict where and when mosquito-borne pathogens may occur our aims were to determine: 1) the spatial and temporal variability in mosquito communities over the late summer and early autumn in a metropolitan region; and, 2) the presence of arboviruses in the various mosquito species at the sites and the implications for mosquito-borne disease risk.

2. Materials and methods

2.1. Study sites

The Sydney metropolitan region (~−33.83, 151.01) is located in New South Wales, Australia. The city has a warm temperate climate with hot summers (mean maximum temperature 25.6 °C; mean minimum temperature 18.3 °C; mean total rainfall 297.2 mm; Figs. 1 and 2) (Sydney (Observatory Hill), Bureau of Meteorology Station #066062). The population of Sydney is close to 5 million, covers an area of about 1800 km^2 and has a relatively high proportion of green-space, with an average of 3 ha parkland to every 1000 residents (Australian Bureau of Statistics; Searle, 2011). Much of the city surrounds the world's largest natural harbour, which is fed by two major rivers, and is bordered on the south by a bay fed by two smaller rivers. The construction and rehabilitation of urban wetlands is becoming increasingly important to improve water conservation, provide habitat for wildlife and enhance local residential areas (Finlayson and Horowitz, 2015; Carter, 2015). However, the community and local authorities remain mindful of the mosquito threat (Webb, 2013). Water Sensitive Urban Design (WSUD) is actively promoted in Australian cities and, in some circumstances may enhance conditions for local mosquitoes (Russell, 1999; Yadav, Woodbridge, Mitsch & Grewal, 2012).

Eleven study sites were chosen from across the region that represented key potential mosquito habitat types (Table 1, Fig. 3). Sites were chosen based on past surveillance data (Webb, Doggett, Willems, Russell, Clancy & Geary, 2001; CW unpublished data)