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SCIENTIFIC NOTE

FURTHER EVIDENCE THAT DEVELOPMENT AND BUFFER ZONES DO LITTLE TO REDUCE MOSQUITO NUISANCE FROM NEIGHBORING HABITAT

BRIAN J. JOHNSON,[1] RUSSELL MANBY[2] AND GREGOR J. DEVINE[1]

ABSTRACT. Little is known regarding the comparative source–sink relationships between primary mosquito breeding sites (source) and neighboring (sink) environments in heterogeneous landscapes. An exploration of those relationships may provide unique insights into the utility of open-space buffer zone mitigation strategies currently being considered by urban planners to reduce contact between mosquitoes and humans. We investigated the source–sink relationships between a highly productive mosquito habitat and adjacent residential (developed) and rural (undeveloped) coastal environments. Our results suggest that source–sink relationships are unaffected by environment. This conclusion is supported by the high level of synchronicity in daily saltmarsh mosquito abundance observed among all surveyed environments ($\beta = 0.67$–0.79, $P < 0.001$). This synchronicity occurred despite the uniqueness of each surveyed environment and the considerable distances of open water and land (2.2–2.6 km) between them. Trap catches, which we interpret as expected mosquito biting nuisance, were high in both residential and rural coastal landscapes (309.4 ± 52.84 and 405.3 ± 62.41 mosquitoes/day, respectively). These observations suggest that existing and planned open-space buffer zones will do little to reduce the biting burden caused by highly vagile saltmarsh mosquitoes. This strengthens the need for empirically informed planning guidelines that alert urban planners to the real risks of human residential encroachment on land that is close to highly vagile mosquito habitat.

KEY WORDS Buffer zones, coastal development, mosquitoes, nuisance, Public Health

Mosquito nuisance and the threat of disease is often given little consideration by urban planners, despite considerable research on the topic and the substantial costs to individuals and government (Dale 2010, Medlock and Vaux 2015, Dwyer et al. 2016). In the Australian southeast, a major source of mosquito nuisance in coastal developments is uninhabited islands dominated by a mixture of mangrove and saltmarsh habitat favorable to highly vagile *Aedes vigilax* (Skuse) (Knight et al. 2012). This and other saltmarsh-associated species represent a significant public health threat, since they are important vectors of the zoonotic arboviruses Ross River virus (RRV) and Barmah Forest virus (BFV) (Jacups et al. 2008, Naish et al. 2011). Owing to the combined health and nuisance risks that these mosquitoes present, considerable efforts are made to control their numbers through area-wide larviciding campaigns. However, inundating tides, dense mangrove canopy, and the occurrence of staggered brood emergence makes complete control extremely challenging (Johnson et al. 2020a). Urban planners are therefore considering alternative mitigation strategies such as open-space buffer zones (Webb and Russell 2019) and vegetation barriers that interrupt or reduce adult mosquito movement between larval habitats and adjacent residential areas.

The use of buffer zones assumes that the presence of refugia-free land around residential developments will discourage dispersal, yet despite their mention in regional mosquito management guidelines (Scott 2002), no firm guidelines on distance, area, positioning, or habitat type are provided, and the practice has limited empirical support (Webb and Russell 2019). Further, little is currently known regarding the comparative source–sink relationships between primary mosquito breeding habitat (source) and neighboring (sink) environments in heterogeneous urban and rural landscapes. This is important, since environments that contain a greater variety of refugia and harborage vegetation may serve as greater population sinks relative to more developed environments (Abella-Medrano et al. 2015, Roiz et al. 2015) by affecting the magnitude and frequency of mosquito dispersal events. Investigating such relationships will fill valuable knowledge gaps regarding the utility of buffer zones against highly vagile saltmarsh mosquitoes in coastal landscapes.

Here, we investigate source–sink relationships between a productive offshore (island) breeding site and adjacent residential and rural sites on the mainland. All study sites were located in the area of Redland City, Queensland, Australia, and separated by 2.2–2.6 km of land or open water (Fig. 1A, 1B). Patterns of daily mosquito abundance and host-seeking activity were analyzed in each study site using emerging smart trap technology (BG-Counter®;

[1] Mosquito Control Laboratory, QIMR Berghofer Medical Research Institute, 300 Herston Road, Brisbane, Queensland, 4006, Australia.

[2] Pest Management, Redland City Council, Redland City Council, Cleveland, Queensland, 4163, Australia.

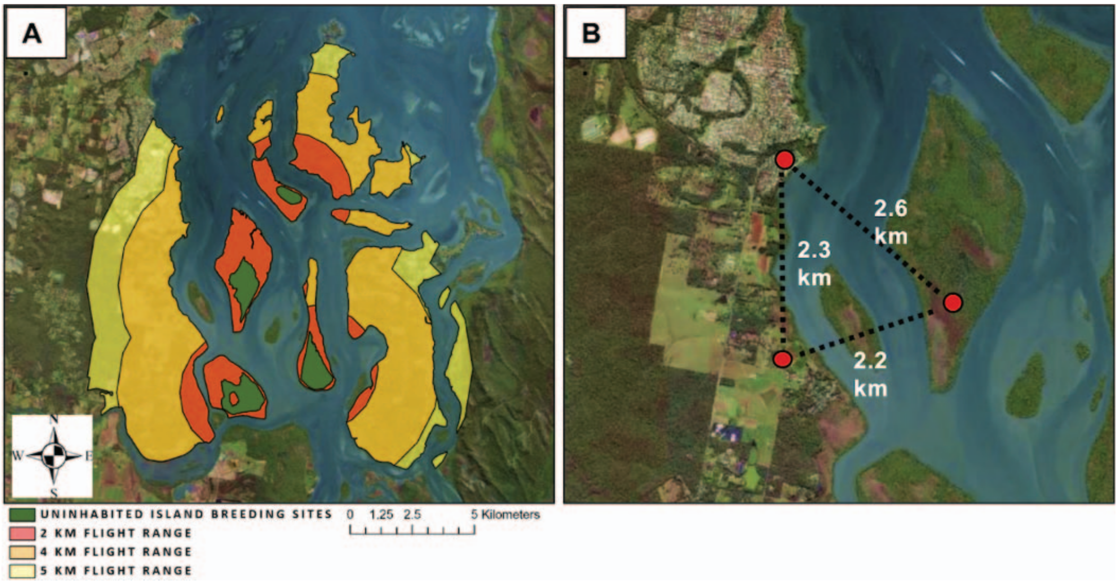

Fig. 1. (A) The area of Redland City, Australia, at risk of mosquito nuisance originating from uninhabited bay islands across a range of known saltmarsh mosquito dispersal distances (2, 4, and 5 km). (B) Location of adult BG-Counter mosquito monitoring stations and distances between trap locations. Depicted flight ranges are based on previous reports from mark-release-recapture experiments (Bryan et al. 1992, Chapman et al. 1999, Webb and Russell 2019).

Biogents AG, Regensburg, Germany). Trap deployment, operation, and statistical analyses followed the methods outlined in Johnson et al. (2020b). Since the BG-Counter cannot differentiate mosquito species, estimated abundances of saltmarsh and freshwater species were determined by multiplying daily collection totals by the community dominance (%) of each species observed at each surveillance interval (2–10 days).

In total, data were collected for 66 complete days from February to May 2020. Repeated measures analysis of variance (one-way ANOVA) of daily collections revealed no significant ($F_{64,128} = 2.7$, $P = 0.08$) difference in estimated saltmarsh mosquito abundance (*Ae. vigilax*, *Culex sitiens* Weid., and *Ae. alternans* (Westwood)) across all sites, but a stronger influence of freshwater species (predominantly *Cx. quinquefasciatus* Say and *Cx. annulirostris* Skuse) in the undeveloped site (23.72 ± 3.01% vs. 49.55 ± 9.65%; Fig. 2A, 2C). This is not surprising, since the area received a substantial amount of rainfall (626.2 mm) during the study period, which coincided with spring tide events that reduced saltmarsh emergence by heavy inundation and flooding. No notable collections of freshwater mosquitoes occurred within the island site. Estimated daily saltmarsh abundance was 324.2 ± 64.16, 309.4 ± 52.84, and 405.3 ± 62.41 for the island, residential, and undeveloped sites, respectively. Host-seeking activity (attraction to CO_2 baited traps) was also similar among all sites (Fig. 2B), although elevated trap catches were observed during the period from 6:00 p.m. to 12:00 p.m. in the undeveloped site. This observation may be attributable to the higher percentage of freshwater species at this site, since freshwater *Culex* spp. have been observed to exhibit longer periods of host-seeking activity relative to saltmarsh *Aedes* spp. (Nasci and Edman 1981, Reisen et al. 1997). Of greatest note was the high degree of synchronicity in estimated daily saltmarsh mosquito abundance observed among all surveyed environments ($\beta = 0.67$–0.79, $P < 0.001$; Fig. 2D–F). The degree of population synchronicity is all the more impressive considering the uniqueness of each surveyed environment and the considerable distances between them.

The results from this study indicate that coastal land use (urban or rural) has little impact on the dispersal of saltmarsh mosquitoes from adjacent offshore mosquito habitat. This suggests that green space does not serve as a significant population sink for dispersing saltmarsh mosquitoes and that the incorporation of open-space buffer zones will do little to reduce nuisance from such species. However, further study is needed, since buffer zones may have some utility against other potential RRV vectors (Jansen et al. 2019) associated with brackish/freshwater swamps such as *Verrallina funerea* (Theobald) that disperse relatively short distances (<1 km; Dwyer et al. 2016). It is therefore imperative that the mitigation strategies proposed by urban planners are empirically informed and guided by local and regional mosquito ecologists and control professionals. This will require more effective communication between regional planning bodies, housing developers, and mosquito control

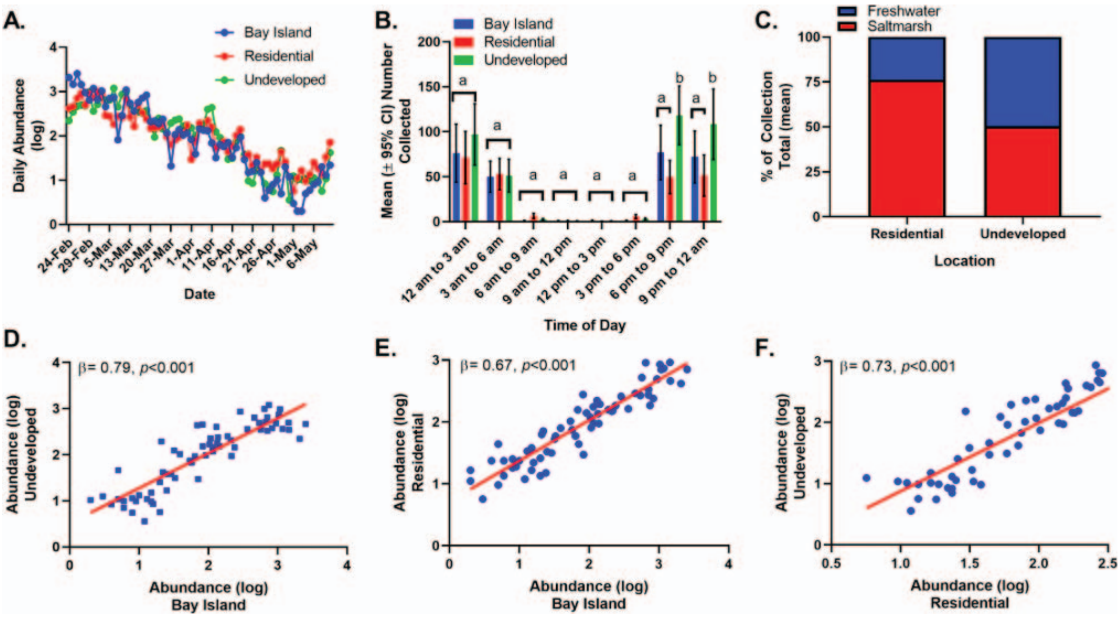

Fig. 2. (A) Estimated daily saltmarsh mosquito abundance within an uninhabited bay island and adjacent residential and undeveloped coastal environments. (B) Daily mosquito (all species) host-seeking activity within the 3 surveyed environments. (C) Mean community presence (% of total collected) of freshwater and saltmarsh mosquitoes observed throughout the study within the coastal residential and undeveloped sites. (D–F) Generalized (least squares) linear regression analysis of daily saltmarsh mosquito abundance between each potential site pairing (e.g., bay island vs. residential). Time (day) was included as a 1st-order autoregressive (AR1) term to account for the temporal correlation in the data. All analyses involving mosquito counts were performed on log + 1 transformed data. Points that do not share similar letters denote statistical significance.

groups. Such consultation would help revise planning directives that currently do little to consider the impacts of urban encroachment on or near productive mosquito habitat.

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REFERENCES CITED

Abella-Medrano CA, Ibáñez-Bernal S, MacGregor-Fors I, Santiago-Alarcon D. 2015. Spatiotemporal variation of mosquito diversity (Diptera: Culicidae) at places with different land-use types within a neotropical montane cloud forest matrix. *Parasit Vect* 8:487.

Bryan J, O'Donnell M, Berry G, Carvan T. 1992. Dispersal of adult female *Culex annulirostris* in Griffith, New South Wales, Australia: a further study. *J Am Mosq Cont Assoc* 8:398–403.

Chapman H, Hughes J, Jennings C, Kay B, Ritchie S. 1999. Population structure and dispersal of the saltmarsh mosquito *Aedes vigilax* in Queensland, Australia. *Med Vet Entomol* 13:423–430.

Dale P. 2010. Australian wetlands and mosquito control—contain the pest and sustain the environment? *Wetlands Aust* 12:1–12.

Dwyer P, Knight J, Dale P. 2016. Planning development to reduce mosquito hazard in coastal peri-urban areas: case studies in NSW, Australia. In: Maheshwari B, Singh VP, and Thoradeniya B, eds. *Balanced urban development: options and strategies for liveable cities*. Berlin: Springer. p 555–574.

Jacups SP, Whelan PI, Currie BJ. 2008. Ross River virus and Barmah Forest virus infections: a review of history, ecology, and predictive models, with implications for tropical northern Australia. *Vector-Borne Zoonotic Dis* 8:283–298.

Jansen CC, Shivas MA, May FJ, Pyke AT, Onn M.B, Lodo K, Hall-Mendelin S, McMahon JL, Montgomery BL, Darbro JM, Doggett SL. 2019. Epidemiologic, entomologic, and virologic factors of the 2014-15 Ross River virus outbreak, Queensland, Australia. *Emerg Infect Dis* 25:2243.

Johnson BJ, Manby R, Devine GJ. 2020a. Performance of an aerially applied liquid *Bacillus thuringiensis* var. *israelensis* formulation (strain AM65-52) against mosquitoes in mixed saltmarsh-mangrove systems and fine-scale mapping of mangrove canopy cover using affordable drone-based imagery. *Pest Manag Sci* 76:3822–3831.

Johnson BJ, Manby R, Devine GJ. 2020b. What happens on islands, doesn't stay on islands: patterns of synchronicity in mosquito nuisance and host-seeking activity between a mangrove island and adjacent coastal development. *Urban Ecosystems* doi: 10.1007/s11252-020-00998-0

Knight J, Griffin L, Dale P, Phinn S. 2012. Oviposition and larval habitat preferences of the saltwater mosquito, *Aedes vigilax*, in a subtropical mangrove forest in Queensland, Australia. *J Insect Sci* 12:6.

Medlock JM, Vaux AG. 2015. Impacts of the creation, expansion and management of English wetlands on mosquito presence and abundance—developing strategies for future disease mitigation. *Parasit Vect* 8:142.

Naish S, Hu W, Mengersen K, Tong S. 2011. Spatio-temporal patterns of Barmah Forest virus disease in Queensland, Australia. *PloS One* 6:e25688.

Nasci R, Edman J. 1981. Vertical and temporal flight activity of the mosquito *Culiseta melanura* (Diptera: Culicidae) in southeastern Massachusetts. *J Med Entomol* 18:501–504.

Reisen W, Lothrop H, Meyer R. 1997. Time of host-seeking by *Culex tarsalis* (Diptera: Culicidae) in California. *J Med Entomol* 34:430–437.

Roiz D, Ruiz S, Soriguer R, Figuerola J. 2015. Landscape effects on the presence, abundance and diversity of mosquitoes in Mediterranean wetlands. *PLoS One* 10:e0128112.

Scott J. 2002. *Guidelines to minimize mosquito and biting midge problems in new development areas* [Internet]. Brisbane, QLD, Australia: Public Health Services, Queensland Government, Queensland Health [accessed April 20, 2020]. Available from: https://www.health.qld.gov.au/__data/assets/pdf_file/0024/422277/14804.pdf.

Webb CE, Russell RC. 2019. Dispersal of the mosquito *Aedes vigilax* (Diptera: Culicidae) from urban estuarine wetlands in Sydney, Australia. *J Med Entomol* 56:1290–1295.