

Research Article

Mosquito Management: Views of Accountability and Their Variance across Neighborhoods in Perth, Western Australia

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• Backyard mosquito breeding; *Aedes notoscriptus*; Mosquito nuisance risk; Urban development; Resident knowledge; Attitudes and practices

Abstract

Public demand for residential land near natural wetlands has risen in Australia without sufficient account being given to the health risks posed by mosquitoes. A study conducted over the 2015-2016 Summer assessed residents' knowledge, attitudes and practices regarding the management of backyard mosquito breeding. Backyard inspections identified breeding habitats and quantified the mosquito fauna associated with residential dwellings. Residents living closer to natural mosquito breeding sites were more likely to regard mosquito management and abatement as a joint responsibility shared with their local government authority and seemed willing to take action within their own residential lot to reduce mosquito breeding potential. As distance from natural mosquito breeding sites increased, resident attitudes seemed to increasingly reflect a view of mosquito control as 'someone else's responsibility'; typically one for government to address. Consistent with this, residents living further from natural breeding sites appeared less likely to identify mosquito breeding potential in their own backyards or to take steps to reduce container breeding capacity. Rather than fear-related communication, public campaigns that emphasize better understanding of mosquito breeding and accurately communicate risks and responsibilities seem important if disease risks posed by mosquitoes are to be mitigated.

ABBREVIATIONS

WA: Western Australia; Km: Kilometers; EVS CO₂: Encephalitis Virus Surveillance Carbon Dioxide traps; RRV: Ross River Virus; BFV: Barmah Forest Virus; PMT: Protection Motivation Theory; KAP: Knowledge, Attitudes, Practices

INTRODUCTION

Perth, Western Australia's (WA) capital and major population center situated on the Swan River has continued to expand with residential development extending to natural mosquito breeding wetlands. Since European settlement in 1829, approximately 70% of Perth's natural wetlands have been lost [1,2], however, with increased housing density in close proximity to wetland habitats, the population impacted by significant mosquito nuisance has grown and with it, an escalating need for intensive mosquito management. In addition, Perth residents have come to expect outdoor lifestyles free from mosquitoes that impact on their amenity. Where once, mosquito-related nuisance and disease risk might have been expected and accepted as part of living within the vicinity of wetlands, these beliefs appear to have become less tolerated, with Local Government Authorities coming under increasing pressure from constituents to improve local mosquito management.

Research has shown that residents living in close proximity to natural wetlands are at an increased risk of contracting mosquito-borne disease [3-5]. The main vectors of disease for the Perth metropolitan region include *Aedes vigilax* (Skuse) and *Aedes camptorhynchus* (Thomson) that both breed in the tidally driven salt marshes that line parts of the Swan River. Ross River virus (RRV) and Barmah Forest virus (BFV) occur throughout Western Australia, although human infection tends to be low in most years for the Perth metropolitan region. However, ever-changing environmental factors (including temperature, rainfall, humidity and tides [6,7]), that drive mosquito populations leading to substantial year-on-year variability in mosquito nuisance and potential disease risk. Further, levels of mosquito-borne diseases are equally difficult to discern, as the threat posed to humans can vary significantly according to the presence of host animals that live within close proximity to humans and play a role in the amplification of these viruses [8]. Consequently, it may not be until residents have occupied new estates in close proximity to wetlands that the incidence of disease actually reaches a level of concern. Confounding these issues; rising environmental consciousness has led to conflicts about the appropriate means of managing environmental health risks [9,10].

While Local Governments and private residents are responsible for the management of nuisance mosquitoes, a joint

effort between State and Local Government is required for the management of disease outbreaks and the control of vector mosquito populations. Notwithstanding the mosquito-control efforts of government bodies on public land, the expansion of development near wetlands in the absence of legislation and land-use planning measures to control mosquito breeding is problematic. There is currently no State-level legislation for the control of disease vectors in Western Australia. In fact, the Town of Bassendean, the location of the present study, is one of few WA Local Government Areas with by-laws requiring owners or occupiers to keep their premises free of mosquito breeding [11]. Even so, backyards inspected within the Town of Bassendean demonstrated that 94% of residents were found to possess containers capable of breeding mosquitoes [12].

The Department of Health WA, in addition to providing assistance to local government in the form of physical and chemical control, have developed a cultural control and communication strategy to educate and warn residents and travelers across the state of mosquito-borne disease risks. The "Fight the Bite" campaign, includes warnings of disease occurrence or virus detections across the State as well as simple messages including cover up (by wearing long, loose, light colored clothing); repel (through the use of insect repellents); and clean up (to remove mosquito breeding habitat from around the home) [13]. These messages are aimed at improving the knowledge of residents in affected areas and to motivate them to take action to protect themselves from mosquito bites.

Protection Motivation Theory (PMT) [14,15] has been widely adopted as a framework for the intervention of health-related behavior change [16,17] with the use of fear to modify attitudes and behaviors. The theory suggests that the use of fear (as information about a threat to an individual's wellbeing) triggers protection motivation, leading to the adoption of adaptive behavior for an overall reduction in the incidents of health-related threats [18]. Such fear-based messages have been used in a number of health-related campaigns, including, but not limited to, cancers [19,20], cigarette smoking [21], alcohol consumption [22], unsafe sexual practices [23] as well as mosquito-borne diseases [24-26].

The current study aims to determine the impact of mosquito nuisance and breeding capacity on private land adjacent to natural wetlands. This included a survey of the Department of Health's cultural communication strategy through a questionnaire to quantify residents' knowledge, attitudes and practices (KAP) with regards to mosquito management. Furthermore, larval container breeding habitat was also surveyed within the resident backyards to allow for direct comparisons between KAP data with distance from natural salt marsh breeding sites along the Swan River. The study aimed to quantify our understanding of the contribution of container breeding mosquitoes from residential backyards against the attitudes and practices of those residents that dwell within the surveyed areas with respect to mosquito management on privately own land.

MATERIALS AND METHODS

The study was conducted in the Town of Bassendean, a metropolitan Local Government approximately 12 km East

of Perth, WA (Figure 1), that contains two well-documented natural mosquito habitats, namely; Ashfield Flats, a 40 hectare tidally driven salt marsh mosquito habitat and Bindaring Park, a brackish waterway running through the suburbs fed by street runoff. The study area is bordered by the Swan River to the South and East, and delineated by major roads to the North and West. The Town of Bassendean comprises medium density housing with a population size of 16,101 residents or 14.89 people per hectare [27].

An aerial map of the study area was first subdivided into 25 quadrants of 500 m² (Figure 1). Within each quadrant backyard surveys for container inhabiting mosquitoes were undertaken and residents were interviewed about their KAP in regards to mosquito control. The number of backyards to be inspected within each quadrant was determined using the random number generator function in Microsoft Excel. The study was planned to be carried out between December 2015 and March 2016, the peak mosquito season as documented by the Town of Bassendean (M. Fatouros pers comm.).

As a result of the random number process, the number of residential lots to be inspected ranged between three and 12 households per quadrant, with a total of 150 residential properties targeted to ensure variation within and between quadrants could be assessed. Study criteria included that where practicable; one house per street was to be inspected, however, in instances where parkland or open space occupied part of a quadrant, more than one house per street was to be permitted. A minimum distance of 200 m was to be maintained between inspected residential lots. In all instances, data collection was to commence as close as possible to the central point of each quadrant. Permission was obtained from the respective residents prior to the initiation of inspections and where households were vacant at the time of inspection; adjacent households were sequentially approached until approval to carry out an inspection was obtained. Once data collection was completed at a residential lot, a parallel, abutting street was targeted for the next inspection until the quota of households for each quadrant was met.

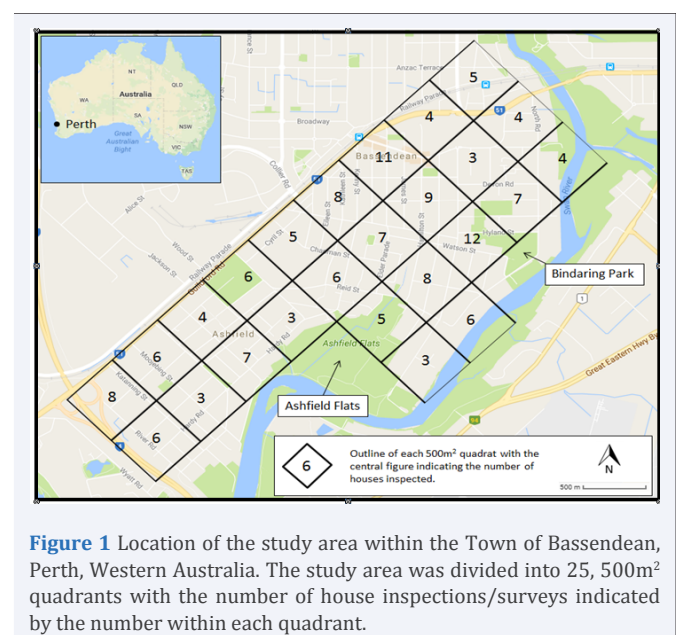


Figure 1 Location of the study area within the Town of Bassendean, Perth, Western Australia. The study area was divided into 25, 500m² quadrants with the number of house inspections/surveys indicated by the number within each quadrant.

The study questionnaire was designed to gain an understanding of residents' KAP in regards to mosquito biology, ecology and risk. Informed consent was gained from a responsible adult resident prior to initiating the questionnaire. The questionnaire was developed by the authors and refined through several stages of peer review in consultation with staff of the local authority in which the study was conducted and the Western Australian State Government Department of Health prior to piloting. The questionnaire was designed to be completed within 10-15 minutes, a time felt to be sufficient to obtain useful data, while not being so demanding that it adversely affected data quality or residents' willingness to participate in the survey as determined through peer review. Nine questions were used to obtain information on the KAP of residents. These included both open and closed ended questions as well as some that allowed multiple-responses. In addition, basic demographic data were also recorded including respondent age, sex, home ownership status, and the number of residents in the household.

A further part of the study plan was that after obtaining consent, an investigator trained in mosquito breeding and larvae collection would conduct a systematic investigation of mosquito inhabiting sites within the property. All potential breeding sites were documented, recording the type (natural versus man-made) and size of habitat, whether the habitat contained water and if so, whether larvae were present. The number and type of all container habitats were recorded and if larvae were present, a sub-sample of the fauna was collected with a turkey baster or mosquito dipper.

Larval samples were placed into vials and labeled with the quadrant and a unique identifier created for each household (1-150). Mosquito larvae were transported to a laboratory in a refrigerated cooler box to protect the larvae from extremes of heat while inspections were being undertaken. Larvae were reared to adults in rearing jars and identified to species using stereo-microscopes and a taxonomic key [28].

To determine the adult mosquito fauna associated with households that were inspected, Encephalitis Virus Surveillance Carbon Dioxide (EVS CO₂) traps were set in each quadrant. Complementing these, traps were also set at the natural breeding sites within Ashfield Flats and Bindaring Park. Each trap was baited with dry ice pellets to provide a carbon dioxide attractant and deployed around 4pm on the day of inspection, with collection the following morning. Adult mosquitoes were killed by placing the trap bag in a container of dry ice. Once dead mosquitoes were placed in labeled vials and transported to the laboratory for identification.

Data were analyzed using SPSS version 22. As the study's ethics approval did not allow for residential address to be collected (due to privacy concerns) all data was averaged within each quadrant and data points placed within the center of each of the 25 quadrants for analysis.

Residents' KAPs were averaged using Likert scales and correlated with adult mosquito density, larval mosquito density and the number of container inhabiting habitats within each quadrant using linear regression analysis.

The data set created for analysis included the GPS location of

central points within each of the 25 quadrants in the study area. The border of the Town of Bassendean was extracted from the ESRI 2013 Local Government Association shapefile for Western Australia [29] and three 500 m buffers were created around the known natural mosquito breeding sites of Ashfield Flats and Bindaring Park using Quantum GIS version 2.18.2 [30] (Figure 2). Buffer zones of 500m (Figure 2) were chosen based on the dispersal of *Aedes notoscriptus* (Skuse) (a container inhabiting species common in the area) with documented dispersal of up to 238 m [31]. The buffer zone was doubled to 500 m to take into account dispersal from residential lots on the edges of quadrants surveyed. Adult and larval mosquito densities were averaged within each buffer to provide an average density of mosquitoes per trap within each buffer for comparison with residents' responses to KAP questions.

RESULTS AND DISCUSSION

A total of 3,329 adult mosquitoes comprising 12 species were trapped and identified across the study area during the Summer of 2015-16 (Table 1). Species were grouped according to breeding habitat to compare with distance from natural mosquito habitats located within public open space at Ashfield Flats and Bindaring Park. Surprisingly, the container inhabiting species were most abundant within natural breeding open space before declining within the 0-0.5 and 0.5-1 km buffer zones. However, *Aedes notoscriptus* (Skuse) was found to increase in abundance across the study area farthest from the natural mosquito breeding sites.

Aedes notoscriptus traditionally breeds in natural containers (rock-pools and tree-holes [28]) and has adapted to occupy container habitats that mimic these traditional natural habitats associated with residential occupation. Its dispersal capacity is generally low with evidence suggesting a dispersal distance of approximately 200 m based on a mark-recapture study in Brisbane, Australia [31]. Nuisance and potential disease risk

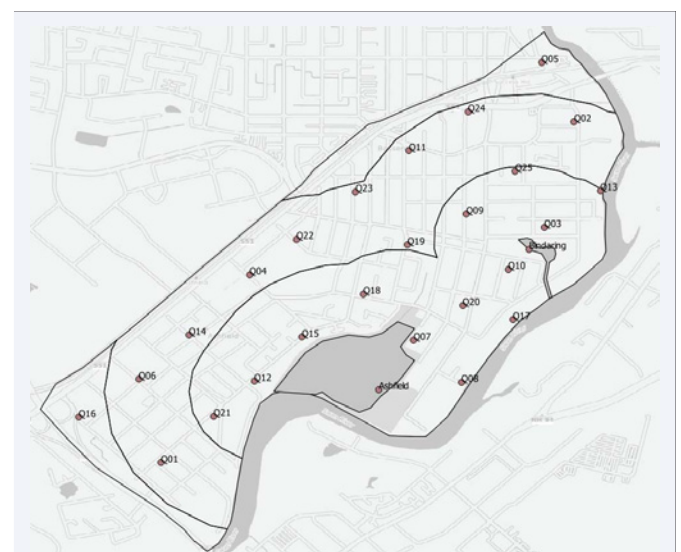


Figure 2 The study area incorporating three 500 m buffer zones from the natural mosquito breeding sites including Ashfield Flats and Bindaring Park (shaded dark grey). Dots indicate centroids of each quadrant with numbers indicating quadrant inspection sequence.

(known as a vector of Ross River virus [32]) was expected to be greater in residential areas than in salt marsh habitats.

Aedes alboannulatus (Macquart) generally breeds in rain fed rock or ground pools [28] and hence could be expected to be found in greater densities in close proximity to the natural mosquito habitats. This species has been found in inland salt affected areas of WA up to 15 gl-1 TDS [33]. Thus, the abundance of this species may be related to ground pools affected by tidal inundation along the Swan River, declining in abundance with distance from these low lying areas.

Culex quinquefasciatus (Say) breeds in fresh to polluted domestic water including container habitats [28]. Its abundance is often associated with street drainage infrastructure [34] and is more abundant in residential buffer zones. It disperses between 0.2 and 1.27 kms depending on environmental conditions [35-37]. While a major domestic nuisance mosquito in many urban areas in Australia, it has been characterized as a poor vector of human disease [38].

Fresh to brackish water species generally demonstrated a similar trend across all 500 m buffer zones, with average abundance fluctuating between 0 and 40 mosquitoes per trap (Table 1). *Aedes clelandi* (Taylor), *Anopheles annulipes* Walker and *Culiseta atra* Lee demonstrated highest abundance at the fresh and brackish wetland breeding sites before declining to average abundances of below 2.5 mosquitoes across all buffer zones. *Culex australicus* Dobrotworsky and Drummond showed a similar pattern decreasing in abundance from the fresh to brackish natural breeding sites across the 0-500 m and 500-1.0 km buffers before increasing to an average of 11.5 mosquitoes in the 1.0 to 1.5 km buffer. *Culex annulirostris* Skuse showed a similar average abundance across all buffer zones between 13.6 to 25 mosquitoes per buffer zone.

Mosquito species that would be found breeding in the natural mosquito breeding sites of Ashfield Flats and Bindaring Park, that are influenced by regular tides associated with salt marsh habitats along the edges of the Swan River were found to decline rapidly with increasing distance from these sites into the surrounding suburban environment (Table 1). The

abundance of these species (particularly *Aedes camptorhynchus* (Thomson) (Southern Saltmarsh mosquito) and *Aedes vigilax* (Skuse) (Summer Saltmarsh mosquito)) showed a dramatic decline from the natural breeding sites. *Culex globocoxitus* (Dobrotworsky) was a possible exception, with a slight increase in density at the greatest buffer distance of 1-1.5 kms. Although dispersal ranges for these species are considerably larger than container inhabiting species, being between 10kms [39] up to 100 kms [28] for *Aedes vigilax* and approximately 3 kms for *Aedes camptorhynchus* [4], there was a marked decrease in abundance in residential buffer zones. This rapid decline in abundance may reflect the environmental conditions at the time of the study, being influenced by neutral weather patterns and a reduction in the number and magnitude of tides that would have stimulated mosquito production.

Of the 12 mosquito species collected throughout the study, four are confirmed as disease vectors of Ross River virus including *Ae. notoscriptus*, *Ae. camptorhynchus*, *Ae. vigilax* and *Cu. annulirostris* [28], making up a total of 64% of all mosquitoes collected. Of these, *Ae. notoscriptus*, *Ae. camptorhynchus* and *Ae. vigilax* actively bite man during the day, with a peak in feeding activity around dusk [28]. *Culex annulirostris* also readily feeds on humans throughout the day, however, blood feeding is predominantly in the evening after dusk [28].

In total, 1,711 potential mosquito breeding container habitats were identified within 150 backyards examined in the study area, equating to an average of almost 11 potential container habitats per household inspected. Of these, 1060 were dry at the time of inspection, 586 were found to contain water without mosquito larvae, and 65 were holding water with mosquito larvae present. An overall House Index (HI) of 26% was found for backyards with active larvae/pupae present, while the Breteau Index (BI) showed 43.33 positive containers per 100 households [12].

The average number of containers found in backyards per household surveyed remained similar as distance increased from natural breeding sites (Figure 3); being 11.2, 12.0 and 10.4 as distances increased from 0.5 kms to 1.5 kms respectively. Although the total number of container habitats and dry

Table 1: The average abundance of adult mosquitoes collected from Encephalitis Virus Surveillance carbon dioxide traps at natural breeding sites and within three buffer zones (0-0.5 kms, 0.5-1.0 kms and 1.0-1.5 kms from the breeding sites). Trapped mosquito species were grouped based on their biology and preferred breeding habitats.

Average abundance of adults mosquitoes at increasing distance from natural breeding sites (Kms)					
Habitat type	Mosquito species	0	0.0-0.5	0.5-1.0	1.0-1.5
Container Breeders	<i>Aedes alboannulatus</i>	5.0	1.4	1.2	6.0
	<i>Aedes notoscriptus</i>	92.0	33.7	33.5	71.5
	<i>Culex quinquefasciatus</i>	30.0	15.5	6.3	5.0
Fresh to brackish water species	<i>Aedes clelandi</i>	13.0	0.8	0.1	2.5
	<i>Anopheles annulipes</i> L.	11.5	1.5	0.5	2.5
	<i>Culex annulirostris</i>	25.0	13.6	19.0	17.5
	<i>Culex australicus</i>	35.5	2.2	4.1	11.5
	<i>Culiseta atra</i>	9.0	0.4	1.4	0.0
Salt marsh species	<i>Aedes camptorhynchus</i>	63.5	1.9	2.4	3.0
	<i>Aedes vigilax</i>	101.0	2.5	3.1	5.5
	<i>Coquillettidia sp. nr. linealis</i>	74.5	1.2	0.5	2.5
	<i>Culex globocoxitus</i>	49.0	7.5	5.0	13.5

container habitats declined at the greatest distance from natural breeding sites, these locations were also found to have the greatest average number of containers holding water without mosquito larvae and average number of containers holding water with mosquito larvae. Thus, although the overall average number of containers declined with increasing distance from natural mosquito breeding sites, the number of containers holding water with and without mosquito larvae increased. These results suggest that as distance from natural mosquito breeding sites increases, backyard habitats for mosquito egg laying and larval development increased.

Adult mosquito abundance was understandably the highest at the known open-space breeding sites of Ashfield Flats and Bindaring Park (Figure 4) before substantially declining within the 500 m and 1 km buffer zones. However, adult mosquito abundance increased in those parts of the study area at greatest distance (1.5 kms) from open-space breeding sites. A significant positive relationship was found between the number of reared mosquitoes collected from backyard container habitats and the number of containers holding water without larvae ($R^2=0.997$; d.f. = 2; $p=0.001$) and the number of containers holding water with mosquito larvae ($R^2=0.976$; d.f. = 2; $p=0.012$). These results suggest that some households are more prone to providing mosquitoes with habitats suitable for deposition of mosquito eggs and the larval stages of mosquito development and are more likely to be located at greater distance from open-space breeding sites.

The total number of containers observed across the three buffer zones was relatively evenly distributed, although the number of open-vessel holding water without mosquito larvae increased as distance from natural mosquito habitat increased. Overall, the number of containers found to contain mosquito larvae in residential backyards was low. The dispersal ability of container inhabiting species is considered to be generally low and may be influenced by oviposition sites provided in adjoined backyards that were not inspected. Container inhabiting species such as *Aedes notoscriptus* have been found to be associated with a range of environmental and micro-climatic conditions including shade, temperature, light, water depth, turbidity and

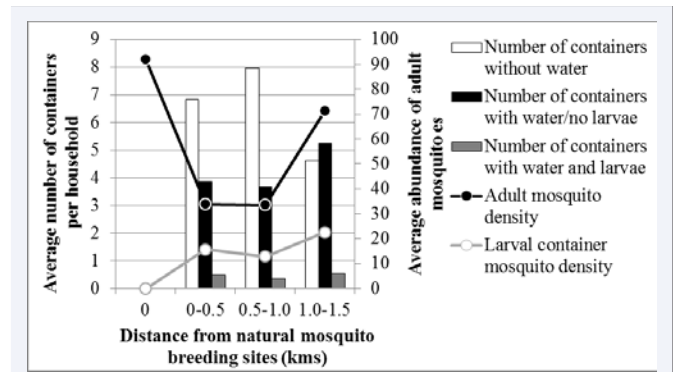


Figure 4 Number of containers in backyards with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River. (Note: black line indicates average number of adult mosquitoes collected from EVS CO₂ traps, grey line represents the number of larvae collected from backyard containers and the bars indicate the number of dry containers, containers holding water with no larvae present and the number of containers holding water with mosquito larvae present).

the presence of competitors. All these factors have been found to influence the oviposition of adult female mosquitoes [40-42]]. Further, the physical attributes of the containers themselves have an influence on oviposition [43]. A detailed examination of the frequency of container habitat, mosquito density, oviposition and dispersal needs to be conducted in order to fully understand the implications of container habitat within suburban areas of Perth, Western Australia [12].

In general, mosquito knowledge was considered to be poor for residents within the Town of Bassendean. When asked which mosquitoes bite humans, between 55% and 70% of residents incorrectly stated that all mosquitoes bite humans (Figure 5). Overall knowledge that only the female mosquito bites humans was slightly greater within the 0-500m buffer zone compared to people at greater distances from natural mosquito development sites.

When asked where mosquitoes breed, residents within the 0-0.5 km and 0.5-1 km buffer zones provided more specific responses spanning a greater number of categories, suggesting they might be more aware of likely mosquito breeding habitats (Figure 6). This is in contrast to residents living further from natural mosquito development sites who stated mosquitoes were found breeding in the river or wetland habitats largely ignoring the possibility of container breeding habitats within their own backyards.

To assess residents' attitudes, responses were generally measure using Likert scales with response options ranging from one to five, reflecting attitudes spanning 'not at all' to 'complete agreement'. Average responses to questions were calculated for each of the 0.5 km buffer zones and compared to average adult mosquito abundance collected from EVS CO₂ traps or as larvae collected from backyard containers. No significant overall relationship was found between responses to the question "How much of a problem are mosquitoes in your area?" with average adult mosquito abundance ($R^2 = 0.187$; d.f. = 2; $p=0.568$ (Figure 7). However, a significant positive relationship was found between

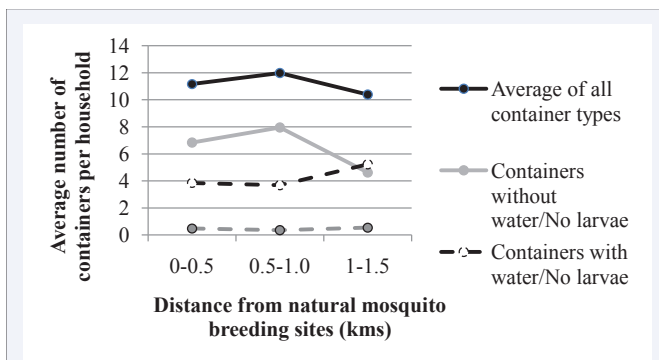


Figure 3 The average number of containers (dry containers; containers with water and no larvae present; containers with water and larvae present) per household with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

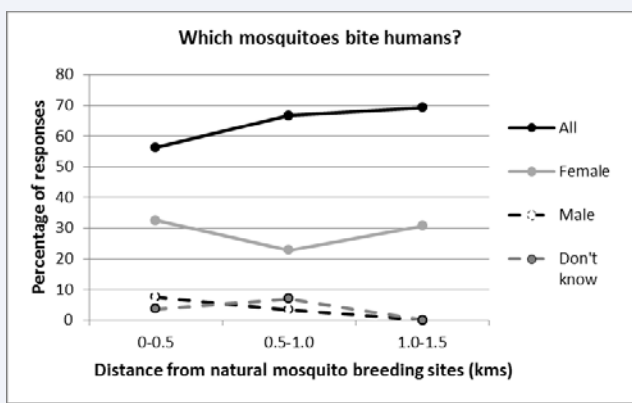


Figure 5 Resident responses to “Which mosquitoes bite humans?” with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

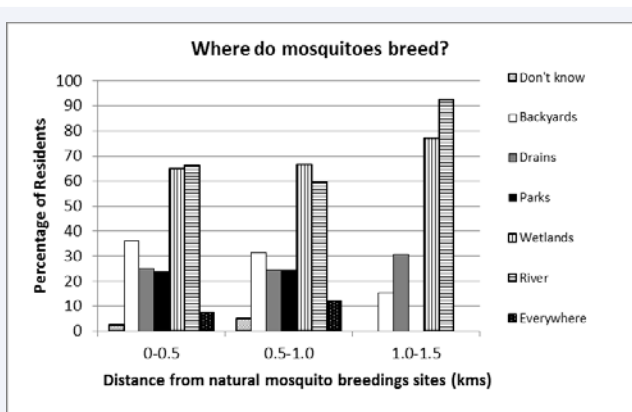


Figure 6 Resident responses to “Where do mosquitoes breed?” with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River. Note: some residents provided multiple responses; hence the percentage of resident responses may be greater than 100%.

resident responses and the number of larvae collected from residents backyards ($R^2 = 0.987$; $d.f. = 2$; $p = 0.006$); suggesting that the presence of backyard mosquito habitats contributes to resident assessments of nuisance risk posed by mosquitoes.

The most common response to the question “Not enough is done in my area to ensure mosquitoes are properly controlled?” was that this was “often” the case regardless of distance from natural mosquito breeding sites (Figure 8). A positive significant relationship was found between the percentage of residents indicating that not enough was done to control mosquitoes with the average number of larvae collected from container habitats within their residential lot ($R^2 = 0.971$; $d.f. = 2$; $p = 0.015$). No other significant relationships were observed with larval container mosquito density.

With regard to resident’s attitudes as to who was responsible for mosquito management, responses were broadly similar among residents living both within 0.5 and 1.0 km of the natural mosquito breeding sites (Figure 9). However, in the study area that was at the greatest distance from the natural mosquito

breeding sites, more residents believed mosquito control was predominantly the responsibility of their Local Government Authority or the State Department of Health rather than that of local householders. This relationship was also found to be positively correlated with average mosquito larval density found in backyard containers ($R^2 = 0.915$; $d.f. = 2$; $p = 0.043$). Similarly, a positive significant relationship was observed with residents responding that “Largely” not enough is done to manage mosquitoes with larval mosquito density recorded from backyard containers ($R^2 = 0.968$; $d.f. = 2$; $p = 0.016$). No other significant relationships were observed with residential responses and adult mosquito density.

The Western Australian average age standardized rate of infection with Ross River virus in the Town of Bassendean is 6.03 per 100,000 head of population, substantially lower than the corresponding State rate of 20.01 (Department of Health, unpublished data, 2017). However, the State rate is highly influenced by rates of infection with Ross River virus in areas across the North and Southwest of Western Australia where

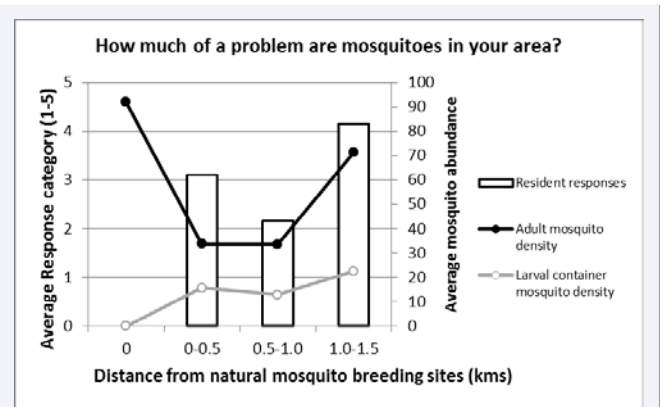


Figure 7 Comparison of resident’s average responses to “How much of a problem are mosquitoes in your area?” with average adult mosquito and larval densities with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

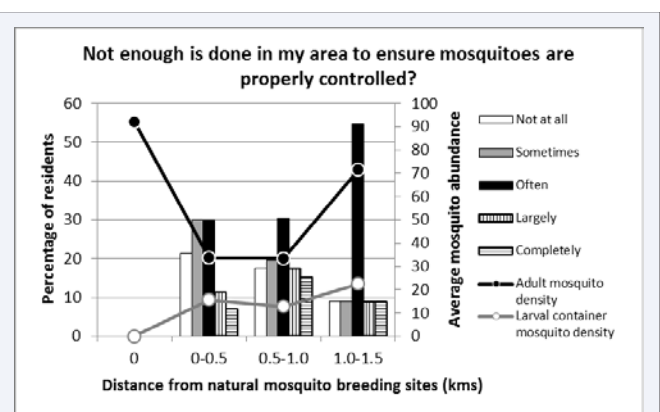


Figure 8 Comparison of average responses to “Not enough is done in my area to ensure mosquitoes are properly controlled?” with average adult and larval mosquito densities with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

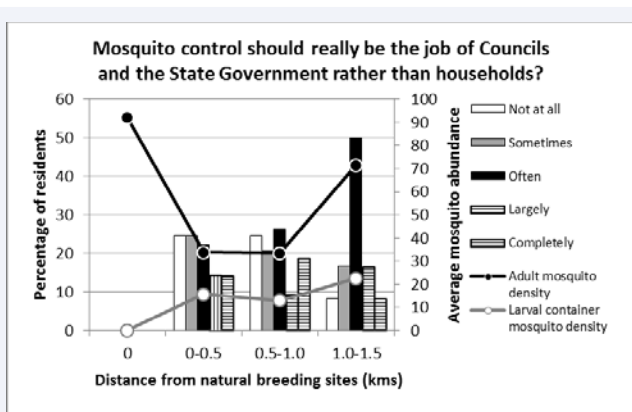


Figure 9 Resident's average responses to "Mosquito control should really be the job of councils and the State Government rather than householders?" compared with average adult and larval mosquito density with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

mosquito breeding occurs more frequently and at a higher rate, in close proximity to host animals, where the transmission cycle can amplify disease risk. Regardless, when asked about their opinion of mosquito risk, respondents in closer proximity to natural breeding sites (at both 0.5 km and up to 1 km from breeding sites) tended to rate it as being similar to other areas in the State, while those at greater distances felt they were at greater risk. Analysis of human disease case data has actually demonstrated significant relationships with distance from mosquito breeding sites at a number of locations in the southwest of Western Australia, indicating an increased risk of contracting Ross River virus within 3kms of mosquito breeding sites [4,5,44]. Mosquito-borne disease risk has also been strongly linked to proximity of mosquito habitats within suburban Perth [3]. Consequently, the data suggests resident's closer to natural breeding sites are better informed about mosquitoes; in this case, with respect to disease risk.

As noted previously, there was a positive relationship found between resident's attitudes toward mosquito risk and the number of larvae collected from backyard containers, which both increased with distance from natural mosquito breeding sites. However, residents' knowledge was greater the closer they lived to the natural breeding sites. In general, this suggests that with better knowledge of mosquitoes, risks were diminished and actual rather than reported backyard practices reduced mosquito breeding within container habitats found in residential backyards. This finding seems important because it runs counter to the logic of accepted public health behavior motivation theories like Protection Motivation Theory, which have previously been used to underpin the design of mosquito health education efforts [45].

Such theories suggest fear is a key motivator of behavior adoption/change [46]. The current study runs counter to this, offering a surprising but potentially important finding. In the context of mosquito control, fear seems less important to actual health related behavior than it is to perceived health risk. It may be speculated that knowledge is more important to self-efficacy and perceived effort insofar as mosquito control is concerned

than fear of mosquito-borne disease. If so, it suggests mosquito education using fear might actually be counter-productive over the longer term.

Part of this counter productivity might relate to another finding of the current study. This was that greater fear of mosquito-related risks and less knowledge about mosquito breeding may lead to stronger attitude formation that mosquito control is an issue predominantly for external stakeholders rather than individual household action (e.g. State/Local Government rather than residents). This seems consistent with the current study's finding that respondents living further away from natural breeding sites were more likely to believe that not enough was being done in their area to manage mosquitoes while concurrently being more likely to contribute mosquito breeding habitats in their own backyards.

Paradoxically, when residents were asked what actions they took to control mosquitoes around the home, the greatest percentage reporting that they took no action (43%) lived within the 0.5 km buffer from natural mosquito breeding sites (Figure 10). At greater distances from mosquito breeding sites, the percentage dropped to around 30% of residents. There was a steady increase in the percentage of respondents that reported using preventative methods (removal of mosquito breeding sites) from the 0.5 km (44%) to the 1 km (51%) and the 1.5 km buffer zones (62%). A similar trend was observed in responses to the use of chemical treatments, which increased from 11% to 21% and 31% with increasing distances from natural mosquito breeding sites respectively. Despite this, no significant relationships were observed between the use of control methods with adult mosquito abundance or larval mosquito abundance.

Respondents that stated that prevention was among one of their strategies for controlling mosquitoes around the home, were asked how they undertook this activity. Across the 0.5 km-1.5 km buffer zones from natural mosquito breeding sites, there was an increase from 35% to 54% respectively in the percentage of respondents claiming they removed stagnant water from around the home (Figure 11). This is similar to the results from a KAP survey undertaken in Malaysia that indicated only 39%

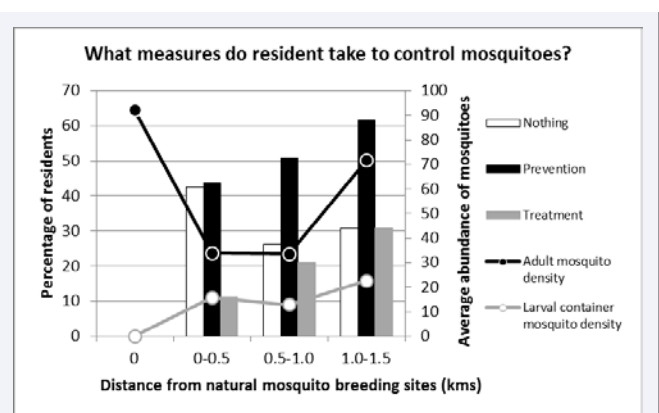


Figure 10 Percentages of residents using control options to manage mosquito populations compared to average adult and larval mosquito density with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

of respondents to maintain a yard free of mosquito breeding containers [47]. Contradicting this, when examining the actual number of containers found on residential lots, there was an increased number of containers holding water and holding water with mosquito larvae present within the most distant buffer zone. A significant relationship was found between the percentage of respondents claiming to remove stagnant water from around the home with an increase in the number of containers actually found on the property ($R^2 = 1.000$; d.f. = 2; $p = 0.002$). No other significant relationships were observed. This is particularly important, indicating that residents may have been biased in their responses to the KAP survey, providing answers they felt were expected by the interviewees which were not substantiated by the backyard inspections.

Of respondents that used outdoor chemical control to manage mosquito populations, few consistent trends were observed (Figure 12). Those that reported never using chemical control was lowest at the greatest distance from natural mosquito breeding sites and highest in the intermediate buffer zone. The reverse trend was observed in residents that sometimes use outdoor chemical control methods with the lowest percentage of responses occurring in the intermediate buffer zone (0.5 to 1 km from natural breeding sites). There was a steady decline in respondents who claimed to “often” use outdoor chemical control methods from the 0.5 km buffer zone to the 1.5 km buffer zone (28%, 21% and 15% respectively). The percentage of residents that always used outdoor chemical control increased from the 0.5km buffer to the 1.5km buffer zone (6%, 17% and 31% respectively) however, this was not found to be associated with adult or larval mosquito densities. In general, resident responses to the use of chemical control for mosquito management varied across the buffer zones and no clear pattern or reasoning could explain when residents perceived the need for chemical control around the home. No significant relationship was observed between residents using outdoor chemical control and adult or larval mosquito densities on the residential properties. These results are similar to a study in Papua New Guinea where they found indifference in resident’s use of mosquito nets, which they linked to a lack of fear of infection with malaria [48]. This contrasts

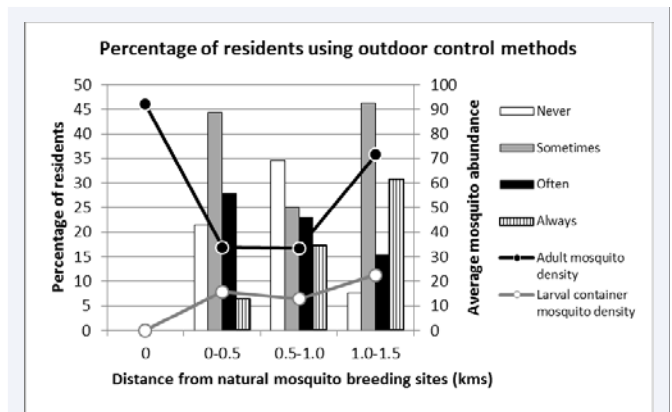


Figure 12 Percentage of residents using outdoor chemical control options to manage mosquito populations compared to average adult and larval mosquito density with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

with a study in the United States that found respondents who complied with prevention for Zika infection to have a stronger fear based response [49].

In the current study, reported strategies to reduce mosquito abundance actually increased with distance from natural breeding sites. Residents claiming to employ chemical treatment (including naturally based products) against mosquitoes increased with distance from natural breeding sites, from 11% to 31%. The latter figure is consistent with results from across WA with an average response of residents indicating that 33% use chemical control methods to reduce mosquito numbers [50].

Once again, the reasons for this can only be speculated. However, it seems plausible to suggest that rather than seeking to deal with mosquito-related nuisance and health risks via chemical means, people living closer to natural breeding sites “choose their battles” more selectively. Perhaps, for instance, they are more selective about times and places for entertaining. In other words, they might have come to accept the realities of their local environment, manage the risks as they can, and avoid exposures when they cannot. This, of course, needs to be assessed via further research.

A seemingly important methodological finding from the current study is that the results of KAP surveys alone might give distorted pictures of public health realities with respect to mosquito control. As a result, KAP surveys should not be solely relied upon to adequately enumerate behaviour and need to be supplemented with assessments as to whether practices claimed by residents are actually employed.

The results of this small-scale study reflect those of residents living within 1.5 kms of natural mosquito breeding sites within a single Local Government area of Perth, Western Australia. Consequently, the findings and interpretations require confirmation through further research in other areas within and outside WA.

Although the study was conducted at the peak of the mosquito-breeding period (Summer of 2015-16), the environmental conditions at that time were not as conducive to mosquito

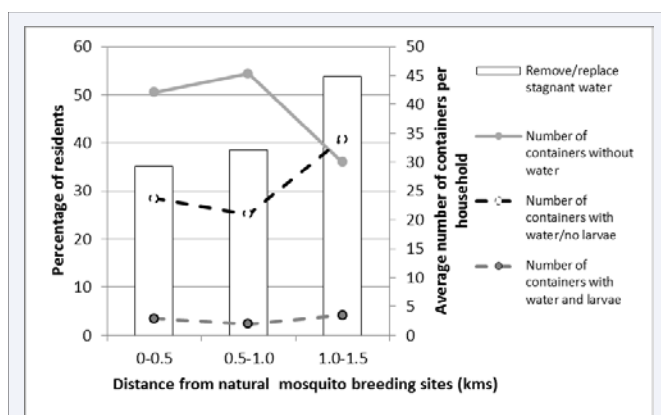


Figure 11 Percentages of residents that remove or replace stagnant water to manage mosquito populations compared to average adult and larval mosquito densities with increasing distance (500 m buffer zones) from natural mosquito breeding sites along the Swan River.

development as had been the case in the prior two years and the attitudes of residents may reflect the reduced mosquito pressure experienced by residents at the time of interview. Responses of residents may vary from year-to-year, dependent on mosquito production from breeding sites and comparison with La Niña weather patterns that lead to increased mosquito numbers.

CONCLUSION

In “The Art of War”, Tzu states “If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle” [51]. Residents living in closer proximity to natural mosquito breeding sites seem to reflect the first exhortation, being more knowledgeable about the issue and more accepting of mosquito management and abatement as a shared responsibility requiring action within their own residential lots to reduce mosquito breeding. However, this study also suggested that as distance from natural mosquito breeding sites increased, the resident perspectives changed, seemingly to ones paralleling the final warning in the quote. In recent times, the tendency in Australian public health campaigns has been to see preventive health issues as being most readily resolved by fear-invoking communications. This has been supported by theories and models that seek to explain health related behavior. However, the current study casts some doubt over both these theories and the effectiveness of fear as a communication strategy, at least insofar as mosquito control is concerned. It also suggests that there might be substantial methodological weaknesses associated with research into health related behavior that relies on KAP approaches alone, without behavioral verification. This study clearly demonstrates a change in residents’ behavior with increasing distance from natural mosquito breeding sites associated with mosquito control efforts, even though a bias was clearly identified in residents’ attitudes and practices compared to their documented actions. These results suggest that stronger correlations may have been observed if residents’ responses to the KAP questionnaire reflected the actual behaviors observed in the quantification of backyard breeding container habitat, suggesting residents responses reflected attitude and behaviors they felt were expected by the interviewer.

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