Aedes Mosquito Control and Surveillance in the Pacific

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ABSTRACT

Introduction: Mosquitoes of the genus Aedes transmit dengue, Zika and chikungunya viruses, and the incidence of these diseases is increasing in the Pacific. This can be attributed to increased movement of people and goods, unplanned urbanisation, and global warming, among other factors. As vaccines are unavailable, we rely on vector control programs to prevent disease transmission. This study aimed to evaluate current practice in vector control and surveillance in 10 Pacific Island countries and identify evidence-based vector control interventions and surveillance methods for use in these countries.

Methods: This study was conducted in preparation for TechCamp New Zealand, 24-26 January 2018, which aimed to work with stakeholders from 10 Pacific nations to reduce the spread of vector-borne diseases in the region. We conducted a literature review of published reviews and meta-analyses evaluating Aedes control and surveillance to find methods appropriate for use in Pacific Island countries. We collected information regarding current Aedes mosquito control and surveillance practice in 10 Pacific countries from TechCamp participants, through a survey, presentation and interview.

Findings: Combinations of vector control interventions, applied appropriately, can prevent disease transmission. Although such programs exist in the Pacific, some interventions do not currently follow best practice. Key barriers to implementing evidence-based practice include lack of targeted education, internet and network coverage, personnel and expertise.

Conclusions: Future goals for the region include the adaptation of current practice to evidence-based practice, and the development of vector and risk factor surveillance for targeted mosquito control. New developments should be sustainable and not reliant on internet or network real-time coverage. Education should be targeted to local communities to maximise community participation.

Key Words: Aedes, Mosquito control, Pacific, Surveillance, Vector control

INTRODUCTION

Mosquitoes of the genus Aedes transmit diseases including Zika virus, chikungunya virus and dengue virus.1 The incidence of disease caused by these viruses in the Pacific has increased significantly over the last decade. Dengue incidence has more than doubled, and in 2015 there were nearly half a million cases of dengue in the West Pacific region alone.2 These mosquito-borne diseases are difficult to control as they have similar symptoms, misdiagnosis is common, and a significant proportion of these infections are asymptomatic allowing unknowing transmission of the virus to a new location.3 4 Although infections are usually self-limiting, symptoms are often debilitating, and infection can have serious consequences including antibody-dependent enhancement if an individual becomes infected, for example, with a subsequent different serotype of dengue virus. This can increase the severity of dengue symptoms and can be fatal.5 As all four serotypes of dengue virus have caused epidemics in the Pacific, this is a concern for the region.6 Zika virus has been associated with Guillain-Barré
Syndrome, and infection of pregnant women can lead to miscarriage, microcephaly or central nervous system abnormalities in babies.\(^1\)

As there is not yet a widely accepted vaccine that can solve the problems of these diseases, we rely upon control of the *Aedes* mosquito to prevent disease transmission.\(^6\) *Aedes* mosquitoes are active during the day and prefer indoor environments, with adult females laying their eggs in still water, often in artificial containers. These habits make *Aedes* mosquito control difficult.\(^1\) Successful *Aedes* mosquito control and surveillance in the Pacific has the potential to reduce the burden of these vector-borne diseases, the cost of outbreak and disease management\(^7\), and the number of vector-borne disease cases entering neighboring countries from the Pacific.

We reviewed the literature for global best practice in *Aedes* mosquito control and surveillance, and outline current vector control and surveillance initiatives in 10 Pacific Island countries. These findings could be used to inform policy decisions and guide investment in Pacific Island countries.

**METHODS**

This study was conducted in preparation for the TechCamp in New Zealand, 24–26 January 2018. TechCamps are practical workshops that bring together trainers and participants who work together to use technology to address challenges.\(^8\) This TechCamp aimed to work with stakeholders from the Cook Islands, Papua New Guinea, Fiji, Samoa, the Federated States of Micronesia, the Republic of Marshall Islands, Niue, the Solomon Islands, Palau and Tonga to enhance capacity to reduce the spread of vector-borne diseases in the Pacific region.

A literature search was carried out to appraise reviews and meta-analyses evaluating *Aedes* vector control and surveillance methods, published between 2010 and December 7, 2017. The MEDLINE search included the subject headings: ‘Zika virus’; ‘Dengue’; ‘Chikungunya virus’; ‘public health surveillance’; ‘sentinel surveillance’; ‘epidemiological monitoring’; or ‘geographical mapping’; in combination with ‘*Aedes*’; ‘mosquito vectors’; or ‘mosquito control’. Other referenced documents and grey literature sourced from Google were also included. For each vector control intervention, effectiveness against *Aedes* mosquito populations and related disease incidence, cost-effectiveness, public acceptability, off-target effects, ease of application, and other relevant information for application (e.g. optimal conditions) was reviewed. For each surveillance method, accuracy in representing disease incidence, cost-effectiveness, feasibility, labour and time requirements, and other relevant information for implementation was reviewed. As the literature advocated use of a combination of interventions\(^9\)-\(^10\), vector control interventions were evaluated within categories to find the interventions and combinations appropriate for use in Pacific Island countries. Surveillance methods were evaluated based on the object of surveillance (e.g. larvae, adult mosquito, disease cases, risk factors for transmission) to find methods appropriate for use in Pacific Island countries. Information collected did not include laboratory-based surveillance.

TechCamp participants from 10 Pacific Island countries provided information regarding current practice in their respective countries.\(^11\) Data was obtained from several participants per country with expertise in the area of mosquito control. Firstly, a survey of participants collected information regarding current vector control and surveillance practice, use of technology, and obstacles to public education and vector control. Secondly, groups of participants from each country delivered a presentation at the TechCamp outlining their country’s vector-borne disease situation, vector control and surveillance practice and relevant legislation. Thirdly, interviews with the presenters from each country answered any remaining questions and clarified discrepancies between the information in the survey and the presentation. Countries who were unable to attend the TechCamp but submitted a survey and presentation answered questions by email correspondence. No ethical approval was required for this study.

**RESULTS**

**Mosquito Control and Surveillance Methods**

Our findings of the most effective *Aedes* mosquito control and surveillance methods are consistent with guidelines established by the World Health Organization that also provide recommendations for effective policy development.\(^2\),\(^10\),\(^12\) This information is available in full in the literature review (available on request) and is summarised below.

For each category of intervention, interventions that were found to be most effective and appropriate for use in Pacific Island countries are listed:

- Chemical larvicides or insect growth regulators (IGRs): pyriproxyfen, temephos,\(^13\) spinosad, diflubenzuron,\(^14\)
methoprene, \textsuperscript{13} essential oils from plants, \textsuperscript{15} biological larvivores: larvivorous fish, \textsuperscript{16} copepods, \textsuperscript{17} toxorynchites (Tox), \textsuperscript{18} chemical adulticide application methods: insecticide-treated screens, \textsuperscript{19} indoor residual spraying, \textsuperscript{20} lethal ovitraps, \textsuperscript{21} indoor space spraying, \textsuperscript{26} personal repellents: N,N-Diethyl-meta-toluamide (DEET), picaridin/icaridin, \textsuperscript{22} novel vector control: Wolbachia, Sterile Insect Technique (SIT) combined with Wolbachia, \textsuperscript{23} environmental/behavioural vector control: community mobilization for container management, community mobilization for source reduction. \textsuperscript{24}

The methods of mosquito surveillance which were found to be appropriate for use in Pacific Island countries were:

- Immature mosquitoes: pupae per person, Breteau index. \textsuperscript{21}
- Adult mosquitoes: ovitraps, Biogents-Sentinel (BGS) Trap, bi-directional Fay-Prince Trap, Mosquitrap, backpack aspirators, mobile phone use. \textsuperscript{25}
- Disease cases: syndromic surveillance systems (e.g. PacNet), online data sources (e.g. internet newswire data) combined with case reporting through health information services. \textsuperscript{27}
- Risk factors for disease transmission: geographic information systems (GIS) combined with mathematical modelling. \textsuperscript{28}

**Implementation**

Evidence suggests that successful vector control programs include multiple interventions targeting different stages of the vector life cycle in different ways. However, the success of any vector control program depends on its careful and considered application. \textsuperscript{9} The most appropriate interventions/methods will vary according to the specific context of resource availability, geography/ecology, culture, daily life, mosquito populations, and resistance to chemicals, among other factors. \textsuperscript{10} For example, an insecticide-treated screen over the door of a house is less effective in an open house layout. \textsuperscript{19} It is also important to consider whether chosen interventions will be successful in combination. \textsuperscript{9}

To maximize use of available resources, it is essential to target vector control to key places and times, highlighting the importance of quality surveillance. \textsuperscript{7} Vector control programs should be sustainable, using interventions where there is local capacity for quality application, follow-up and evaluation. \textsuperscript{12} Finally, in order to conserve resources, countries need to consider how current practice can be improved before introducing a new vector control or surveillance intervention. \textsuperscript{19}

**Current Practice in Pacific Island Countries**

TechCamp participants from 10 Pacific Island countries provided information regarding current practice in their respective countries as outlined in Table 1. A ‘tick’ indicates use of the intervention in that country, with two ‘ticks’ signifying the intervention is backed by published evidence. Although in many cases delivery of the interventions is inconsistent across space and time, some infrastructure is in place, and this information allows for current practice to be extended rather than a new intervention introduced.

All countries have vector control programs with multiple interventions targeting different stages of the mosquito life cycle. All countries use chemical adulticides, most commonly delivered through outdoor spraying. Many countries combine this with the use of chemical larvicides or insect growth regulators, or biological larvivores. Behavioral community-based vector control is a major strength in the Pacific region with all the countries listed reporting community clean-up or water container management campaigns. One country is trialing the use of Wolbachia as a novel biological vector control method.

Another strength in the Pacific region is the surveillance of probable disease cases through the use of PacNet, a syndromic disease surveillance system, in all countries included. To fast-track identification of potential outbreaks, syndromes are reported instead of disease cases. Two such syndromes are prolonged fever, and acute fever and rash, which could indicate dengue, Zika or chikungunya virus infection. \textsuperscript{26} However, surveillance of other outbreak risk factors varies widely across the region. In some countries, surveillance of risk factors, and immature and adult mosquito population counts also informs mosquito control, but in other countries syndromic surveillance is the only indication of disease transmission risk.

Many Pacific countries have specific policy and legislation to guide and sustain vector control programs, although some countries incorporate vector surveillance and control under other existing public health legislation.
Table 1: Current Practice in Pacific Island Countries

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<th>Cook Islands</th>
<th>Papua New Guinea</th>
<th>Fiji</th>
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IGR: Insect growth regulator

One tick indicates interventions, methods, policy or legislation in this area.
Two ticks indicate the use of evidence-based vector control or surveillance supported by published literature.
DISCUSSION

There are surprisingly few high quality studies assessing the effectiveness of commonly used chemical adulticides and larvicides and effective delivery methods.\(^1\) Many countries make pragmatic decisions in their choice of adulticides and larvicides and our findings indicate that infrastructure is generally in place that would allow for adaptation to more effective interventions and delivery without requiring the introduction of a whole new program. This is especially true for chemical adulticides, with many countries using outdoor spraying rather than indoor use, where the adult *Aedes* mosquito is more often found.\(^20\) Reasons for using less effective interventions may include public perception, high cost and poor availability of effective interventions. TechCamp participants explained that often the public believe it is the responsibility of the government to control mosquito populations, and so governments prefer the most visible methods such as outdoor spraying of chemical adulticides at midday. Some participants explained that cost and availability limit their vector control methods. For example, one participant explained that disease outbreaks local authorities sometimes run out of their preferred larvicide and apply diesel oil to outdoor ponds to suffocate mosquito larvae by forming a thick oily layer on the water surface. It is important that governments and development partner nations who supply mosquito control resources to Pacific Island countries choose cost-effective, evidence-based methods.

The use of a Pacific-wide syndromic disease surveillance system that includes ‘fever and rash’ allows for rapid detection of potential mosquito-borne disease outbreaks in all countries included in this study. Potential outbreaks can be investigated, and appropriate control measures put in place. However, gaps in the surveillance of outbreak risk factors indicate that targeting of vector control resources prior to disease outbreaks could be improved. Many TechCamp participants commented that often the public only perceive disease outbreaks to be cause for action, and do not engage with outbreak risk factor surveillance or mosquito control when there are no outbreaks. Reasons for this may include lack of targeted education. While information is often available to the public, it is delivered at a national level and participants suggested that this may not be appropriate to the language, culture or context of communities, and so local interest is low. While social media can reach a wider audience, participants suggested that village consultations better encourage local action.

Other barriers to comprehensive surveillance include unreliable internet and cellular coverage and lack of staff and training. There is a need for investment in inexpensive vector surveillance methods that allow for poor internet or cellular coverage and do not require extensive training or personnel. An example of such a surveillance tool that was demonstrated at the TechCamp is the Centers for Disease Control and Prevention (CDC) Epi Info™ Vector Surveillance application. This application allows recording of mosquito surveillance data on a mobile device offline that automatically uploads data to an online database when internet connection is available. The application automatically calculates indices and generates maps and trends by date and location.\(^29\) Intersectoral communication of relevant data also needs strengthening. In some countries, while ecological risk factors for disease transmission are being recorded, the data collected are not used to inform mosquito control.

Finally, there are several limitations to this study. Firstly, findings relate to the *Aedes* mosquito only and cannot necessarily be extended to the *Anopheles* mosquito, which transmits the malaria parasite with a different behavioural pattern. Secondly, results regarding surveillance only include surveillance of vector, disease cases and outbreak risk factors, and do not include laboratory-based surveillance. Thirdly, interventions are used inconsistently within the countries included in the study and information collected did not detail the extent to which they are implemented.

CONCLUSION

Priorities for the Pacific region include the adaptation of current interventions to evidence-based interventions, as well as the development of sustainable surveillance initiatives for disease outbreak and risk factors, and vector control policy, planning and legislation. To increase community participation, education should be targeted to local communities.

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