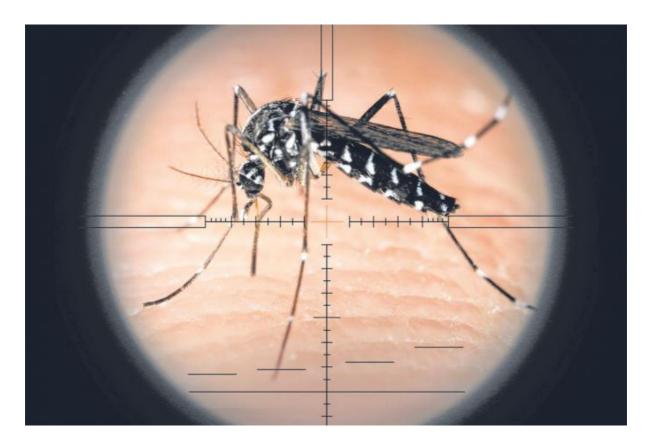
Monitoring Mosquitoes in Singapore: Can Citizens Bite Back?



Cassandra Tho Wen Shu ESA80436: MSc Thesis in Environmental Sciences 26 May 2018

Supervised by: Dr. ir. Arnold van Vliet

Environmental Systems Analysis Group Wageningen University and Research



Monitoring Mosquitoes in Singapore: Can Citizens bite back?

Cassandra Tho Wen Shu (920720829210) MSc Thesis in Environmental Sciences Environmental Systems Analysis

26 May 2018

Supervisor:

Dr.ir. Arnold J.H. van Vliet

Environmental Systems Analysis Group Wageningen University & Research Postbus 47, 6700 AA Wageningen Tel: 0317 485091/484812 Email: arnold.vanvliet@wur.nl

Examiner(s):

1st – Dr ir Arnold van Vliet 2nd – Prof. dr Rik Leemans

Disclaimer: This report is produced by a student of Wageningen University as part of his/her MSc-programme. It is not an official publication of Wageningen University & Research and the content herein does not represent any formal position or representation by Wageningen University & Research.

Copyright © 2018 All rights reserved. No part of this publication may be reproduced or distributed in any form or by any means, without the prior consent of the Environmental Systems Analysis group of Wageningen University and Research.

Preface

I first heard about 'citizen science' when I was sitting in my first lecture of my Master's study, in the course *ESA21806: Principles of Environmental Science*. Having worked with different people from all walks of life to build and bridge communities in my previous job (before my Master's), I realized that I actually enjoyed working with people and seeing people come together for a cause. I was also interested in topics related to the environment and biodiversity. So when I heard about the concept of 'citizen science' from Mr Citizen Science himself, Arnold van Vliet, I knew immediately I wanted to do something related to citizen science for my thesis.

My original plan I had was to find out if Arnold had any citizen science projects for me to hop on but when I approached him, he had just given a talk in my communications course and shared about the Global Mosquito Alert. So I shared with him about the 'mosquito problem' in Singapore and then it became my thesis topic which I would go on to work on it for the next few months.

Working on this thesis has been the most challenging, but also very rewarding part of my time as a student. I had to approach stakeholders in Singapore whom I have never met before to do interviews; get all my friends and contacts to share and help me fill out my survey; befriend SPSS for the analysis of the collected data; find and read papers for information to back my results and discussions; and also to give presentations at the start and end of my thesis, all of which required a lot of stepping out from my comfort zones.

However, while writing a thesis has always been seen like an individual thing, where you are all alone and no one besides you and your supervisor really knows what your project is about, I was never really alone in this journey and I have the following people to thank for this:

Arnold – Thank you for being the best (& first thesis) supervisor I could ever have for my thesis. Your enthusiasm, dedication and experiences with citizen science is an inspiration to me. Thank you for believing in me and for always reassuring me of the value of my project when I feel like I have reached a brick wall; and for all the detailed feedback you give despite your busy schedule; for roping me into The Global Mosquito Alert and for the subtle life teachings you inject in our weekly meetings.

My Wageningen family – (1) Wonderteam (Qian, Rafika, Valentina, Vandru, Davide) – Glad to have known you guys since the start of Period 1, and have all of you to go through the thesis journey together, even though we all worked on our own projects, we were never really alone because misery loves company (haha). Thank you for all the SPSS help, all the dinners, all the rounds of Saboteur and laughter to destress and for your friendship. (2) Sunday Singaporeans (Hazimah, Petrina, Yueling, Samantha, Ian) – Though I came to Wagey to avoid masses of Singaporeans, I am glad we all found each other eventually cause our frequency all almost the same even though we are all studying different things! Thank you for all the thesis/life advices, being my Masterchefs and indulging in my SG food cravings, all the Carcassonne rounds and also for your friendship.

Friends and family in Singapore – You know who you are, thank you for the encouragement, all the help with Microsoft Excel, keeping me updated on SG happenings and for simply being my listening ears, 10,440km away. To my parents, for attempting to understand what my thesis is all about, for driving me to my interviews while I was in Singapore; and for always knowing when to tell me to take a break whenever I was stuck.

Interviewees & survey respondents – Thank you for taking time out of your busy schedules to meet with me and share insights on Singapore's mosquito scene and your ideas and enthusiasm for a citizen science initiative with me; and for those 319 respondents who took time to fill out my very long survey, thank you for giving me data (& nice results) for my thesis!

I will leave you with this African Proverb that I feel is very apt – for citizen science, and for life in general:

"If you want to go fast, go alone. If you want to go far, go together."

Cassandra Tho 26 May 2018

Table of Contents

PKEF	ACE	3
<u>SUMI</u>	MARY	6
<u> 1 II</u>	NTRODUCTION AND BACKGROUND	9
1.1	MOSQUITO-BORNE DISEASES IN SINGAPORE	9
1.2	CITIZEN SCIENCE NETWORKS FOR MOSQUITOES	11
1.2.1	Muggenradar in The Netherlands	12
1.2.2	GLOBAL MOSQUITO ALERT	13
1.3	KNOWLEDGE GAP AND PROBLEM STATEMENT	13
1.4	RESEARCH OBJECTIVE, QUESTIONS AND RELEVANCE	13
1.4.1	OBJECTIVE OF PROJECT	13
1.4.2	1	13
1.4.3	RESEARCH RELEVANCE	14
1.5	OUTLINE OF REPORT	14
<u>2</u> <u>N</u>	METHODOLOGY FOR DATA COLLECTION AND ANALYSES	15
2.1	LITERATURE REVIEW	15
2.2	Interviews	15
2.3	ONLINE PUBLIC PERCEPTION SURVEY	16
2.3.1	Extended Parallel Processing Model	16
2.3.2	277.00-120.7.07.7.07.00	16
2.3.3	DATA ANALYSIS OF SURVEY RESULTS	17
2.4	MOSQUITO NUISANCE REPORTING DATA	18
<u>3</u> <u>N</u>	MOSQUITO SCENE IN SINGAPORE	20
3.1	INTRODUCTION TO THE DENGUE SURVEILLANCE AND MOSQUITO SCENE IN SINGAPORE	20
3.2	MOSQUITO SURVEILLANCE	21
3.2.1	GRAVITRAPS	21
3.2.2	NEA OFFICERS CONDUCTING HOUSE VISITS	22
3.2.3	LABORATORY AND FIELD RESEARCH	22
3.3	MOSQUITO CONTROL	23
3.3.1	Project Wolbachia	23
3.3.2		23
3.3.3	,	24
3.3.4	,	24
3.3.5	MOBILE PHONE APPLICATIONS	25
<u>4</u> <u>P</u>	REVENTIVE BEHAVIOUR OF RESIDENTS IN SINGAPORE	28
4.1	RESPONDENT CHARACTERISTICS	28
4.2	PREVENTIVE MEASURES TAKEN BY RESIDENTS IN SINGAPORE	28
4.3	FACTORS THAT INFLUENCE PREVENTIVE BEHAVIOUR	29
<u>5</u> <u>E</u>	VALUATION OF THE DUTCH MOSQUITO CITIZEN SCIENCE NETWORK	34
<u>6</u> <u>S</u>	TAKEHOLDERS' PERCEPTION OF A CITIZEN-SCIENCE APPROACH	38
6.1	INTRODUCTION TO INTERVIEWS WITH STAKEHOLDERS	38

6.2	PERCEPTION ON CURRENT SURVEILLANCE AND CONTROL EFFORTS	39
6.3	APPLICABILITY OF CITIZEN SCIENCE INITIATIVES IN THE SINGAPORE CONTEXT	39
6.4	POTENTIAL CHALLENGES OF A CITIZEN-SCIENCE APPROACH	40
6.5	STAKEHOLDERS' WILLINGNESS TO PARTICIPATE IN A CITIZEN-SCIENCE APPROACH	40
<u>7</u> <u>I</u>	NFLUENCING PARTICIPATION IN CITIZEN SCIENCE PROJECTS	41
7.1	GROUND SENSING OF "CITIZEN SCIENCE" IN SINGAPORE	41
7.2	WILLINGNESS TO PARTICIPATE IN CITIZEN SCIENCE PROJECTS	41
7.3	FACTORS INFLUENCING PARTICIPATION IN MOSQUITO-RELATED CITIZEN SCIENCE PROJECTS	41
7.4	PREFERRED COMMUNICATION CHANNELS AND TYPES OF INFORMATION	45
<u>8</u> <u>I</u>	DISCUSSION	48
8.1	CURRENT SURVEILLANCE AND CONTROL METHODS	48
8.2	FACTORS INFLUENCING PREVENTIVE MEASURES	50
8.3	EVALUATION OF THE DUTCH MOSQUITO CITIZEN SCIENCE NETWORK	53
8.4	STAKEHOLDERS' PERCEPTION OF A CITIZEN-SCIENCE APPROACH	54
8.4.1	ADDED VALUE OF A CITIZEN-SCIENCE APPROACH	54
8.4.2	ATTRACTING PEOPLE TO PARTICIPATE IN CITIZEN SCIENCE PROJECTS	55
8.4.3	B ENSURING SUSTAINABILITY OF CITIZEN-SCIENCE APPROACHES	56
8.4.4	TYPE OF INFORMATION WANTED FROM A CITIZEN-SCIENCE APPROACH (BY STAKEHOLDERS)	57
8.5	INFLUENCING PARTICIPATION IN CITIZEN SCIENCE PROJECTS	57
9	CONCLUSION & RECOMMENDATIONS	61
<u>10</u>	REFERENCES	64
APP	ENDIX A – INTERVIEWEE LIST & INTERVIEW GUIDELINES	67
APP	ENDIX B – ONLINE PUBLIC PERCEPTION SURVEY	69

Summary

Singapore is a sunny, tropical island, located just one degree above the equator. Singapore is densely populated (7,700 persons per km²) and has often been cited as a top country in terms of mosquito surveillance and vector control. Many different surveillance and control measures are currently in place to monitor mosquitoes and to keep them away. As such, one would expect Singapore to have dengue and other mosquito-borne diseases (MBDs) under control. Unfortunately, this is not the case. Singapore has, over the past few decades, been increasingly affected by MBD outbreaks. Some of the notable outbreaks includes dengue in 2005 (14,006 cases and 27 deaths) and 2007 (8286 cases and 24 deaths); chikungunya in 2008; a resurgence of dengue in 2013 and 2014; and Zika in 2016. Besides these epidemic outbreaks, dengue incidences occur annually. The high population density together with the tropical climate have been postulated to contribute to this dengue problem.

While many surveillance and control programs are in place, many mosquitoes still go unnoticed, especially those that breed within residential premises. This presents an opportunity to survey and control mosquito vectors through a community-based citizen-science approach. Several citizen-science projects currently focus on mosquito surveillance in Europe, including the Dutch Muggenradar. Muggenradar gets their citizen scientists to collect mosquito samples and submit nuisance reports. Together with other mosquito-related citizen-science projects, a Global Mosquito Alert Consortium was established in 2017 to monitor mosquito populations. This initiative plans to create a real-time monitoring of mosquito-population trends globally. Furthermore, pooling of worldwide resources, knowledge and information helps to better understand the mosquito vectors, predict outbreaks and support public health management.

This thesis aims to investigate if Singapore's existing mosquito-monitoring program can be extended with a citizen-science approach and contributes towards the vector control department of its National Environment Agency (NEA). The thesis also aims to provide a better understanding of how society perceives mosquito-borne diseases and how to better engage the public in data collection for mosquito surveillance and control. To achieve these aims, five research questions (RQs) were formulated. The methods used in this study were: (i) literature review; (ii) an online public-perception survey; (iii) analysis on nuisance reports submitted by the public to Muggenradar; (iv) interviews with stakeholders involved in the mosquito scene in Singapore; and (v) a statistical analysis of the collected survey data.

RQ1 on the organisation of the current Singaporean mosquito surveillance and control addressed many different programs which were implemented and handled by NEA and the Environment Health Institute (EHI). While these programs are implemented top-down, there are also efforts to involve, educate and raise awareness amongst the public. However, how large the outreach is currently unknown. NEA and the Municipal Services Office (MSO) have both developed mobile applications (i.e. myENV and OneService) that both allow the public to report mosquito breeding spots. However, only few people apply these apps.

RQ2 described preventive behaviour towards mosquitoes and MBD. I surveyed public perception towards mosquitoes and MBDs; respondents' preventive behaviours; and their willingness to participate in a citizen-science approach. I found that people in Singapore did not carry out preventive behaviours singly, but rather in combination with other preventive measures. This finding hints that people are probably worried about mosquitoes and contracting MBDs. In addition, I found that 'perceived severity' and 'perceived self-efficacy' were important factors that determined whether people did preventive behaviour.

In order to advocate for and show the benefits of a citizen-science approach, I assessed the usefulness of citizen-contributed data (RQ3). An analysis of the Muggenradar data combined with a mosquito-

nuisance prediction model showed that reporting nuisance levels did not well correlate with the model's outcome. The reasons for this include limitations in the methodology and in the prediction model used, and the absence of a structured reporting system. However, this does not mean that there is no value in a citizen-science approach, but rather that there is more room for improvement to make the data submitted by the public more useful and valuable for science. An important finding from Muggenradar is that media attention is important. Media stimulates outreach and attracts and retains volunteers. Media attention also plays a likely role to inform and instruct people on what information to report.

As the mosquito problem is a complex problem that cannot be handled by one person or agency alone, I carried out interviews with stakeholders involved in the mosquito scene in Singapore. This was done to answer RQ4. Most stakeholders were keen on a citizen-science approach and only, few were hesitant. Some of their main concerns revolved around the approach's added value; the continued attraction and retaining volunteers; sustaining projects; and the characteristics of the collected information.

Next, for a citizen-science approach to work, citizens need to be willing to participate. As such, the final RQ addressed factors that influence active participation. The online survey showed that a large majority was keen to participate and also acknowledged that controlling mosquitoes is a shared responsibility between the government, town councils, families and the individuals. Participants were motivated because they wanted to better protect themselves and their loved ones from mosquitoes and MBDs by contributing to mosquito surveillance and control. Their preferred choice to receive information are notifications through social media, television and mobile phone. People are interested to be alerted to MBD outbreaks in their area, and informed on mosquito seasons and protecting their friends and families from mosquitoes and MBDs.

Finally, I conclude that a citizen-science approach can be used to extend existing mosquito surveillance and control efforts. I recommend that NEA and MSO better cooperate and align their reporting format for mosquito breeding and nuisance, and develop a more structured and comprehensive reporting system within both their apps, to make it more user-friendly for people to submit observations. Implementing this recommendation helps to collect more data and also ensures data comparability. This could potentially feed into Global Mosquito Alert. Knowing what information (e.g. alerts on mosquito seasons and information on mosquito protection) is needed by potential participants is important to attract and retain their interest and to motivate their continued participation in the project. Furthermore, as Singapore is considered a role model on how mosquito surveillance and control is conducted, incorporating citizen-science approaches into existing efforts likely encourage other countries to follow as well. Singapore should also become part of the Global Mosquito Alert Consortium, to share best practices and contribute to the global mosquito monitoring.

Acronyms list

CVPA – Control of Vectors and Pesticides Act

DPVG – Dengue Prevention Volunteers' Group

EHI – Environment Health Institute (Singapore)

EPPM – Extended Parallel Processing Model

HDB flats – Housing Development Board flats

KNMI – Royal Dutch Meteorological Institute

MBD – Mosquito-borne diseases

MOH – Ministry of Health (Singapore)

MSO – Municipal Services Office (Singapore)

NEA – National Environment Agency (Singapore)

UNEP – United Nations Environment Program

VCO – Vector Control Operators

WHO – World Health Organization

1 Introduction and Background

1.1 Mosquito-borne diseases in Singapore

Singapore is a sunny, tropical island, located just one degree above the equator. Singapore is densely populated with an estimate of 7,700 persons per km² based on an extent of 719 km² and a population of 5.5 million. Singapore has over the past few decades been increasingly affected by various vector-borne disease outbreaks and in particular, by mosquito-borne diseases (MBDs). Some of the notable outbreaks includes the battle with dengue in 2005 (14,006 cases and 27 deaths) and 2007 (8286 cases and 24 deaths) (Ler et al., 2011); chikungunya in 2008; a resurgence of dengue in 2013 and 2014; and Zika in 2016. Besides these epidemic outbreaks, dengue incidences occur every year (Figure 1).

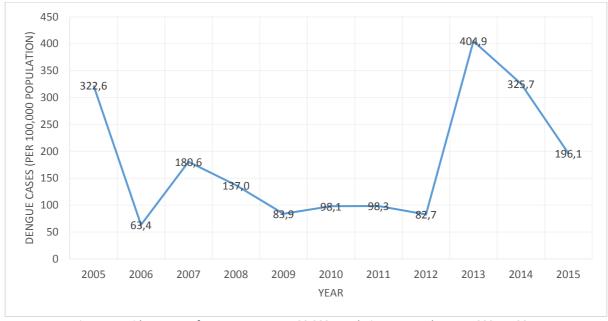


Figure 1. Incidence rate of Dengue cases per 100,000 population per year between 2005 to 2015 (Data retrieved from: https://data.gov.sg/dataset/vector-control-data-dengue-outbreak-statistics)

With its position just above the equator, Singapore experiences a tropical climate with the average temperatures ranging between 25.8°C and 31.9°C and an annual rainfall of 1267mm¹. The increase in average temperatures due to global climate change as well as the high rainfall that comes with a tropical climate (Figure 2); the increase in mobility due to globalization and the decline in immunity level of the population are some of the reasons that contributes to the resurgence of Dengue in Singapore (Hii et al., 2009).

9

¹ Singapore in Figures 2016. (2017). Singapore. Retrieved from http://www.singstat.gov.sg/docs/default-source/default-document-library/publications/publications and papers/reference/sif2016.pdf

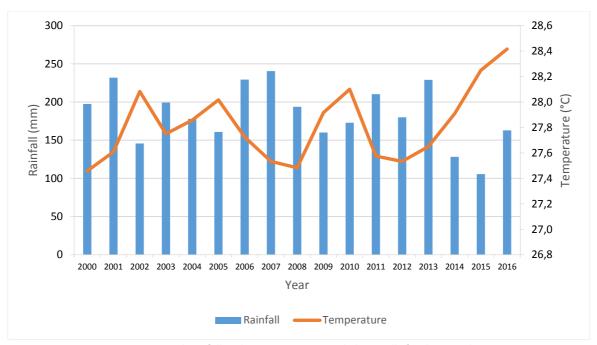


Figure 2. Average annual rainfall and temperatures recorded annually for the period 2000 to 2016 (Data retrieved from Department of Statistics, Singapore)

Dengue, which is endemic in Singapore, is usually spread by the female mosquitoes of the *Aedes aegypti* and *Aedes albopictus* species (Liew & Curtis, 2004) and they are easily identified because of the distinct black and white stripes on its body. The *Aedes* mosquito is known to breed in areas with clean, stagnant water, which can be easily found in homes and public areas². According to Singapore's National Environment Agency (NEA), almost half (47%) of breeding sites are mostly found in residential premises (Figure 3) and is usually detected in water left in domestic containers, flower pot plates, ornamental containers and even toilet bowls (Figure 4).

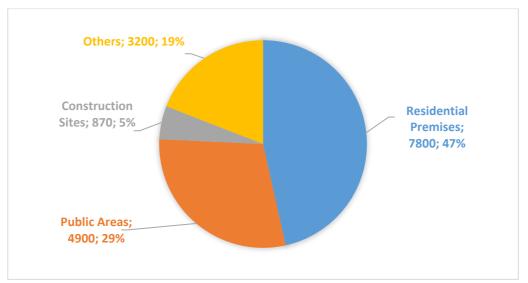


Figure 3. Pie chart showing the distribution of breeding sites recorded by NEA for the period of Jan 2016 - Dec 2016.

(Data retrieved from NEA's Dengue Surveillance Data Reports)

² Prevent *Aedes* Mosquito Breeding. (2017). Retrieved May 28, 2017, from http://www.nea.gov.sg/public-health/dengue/prevent-aedes-mosquito-breeding



Figure 4. Infographic of the Top 5 Breeding Habitats found in Residential Premises. This is representative of the data collected between 2012 to 2016. (Retrieved from The Straits Times, "How to keep homes mosquito-free and avoid the \$200 fine" Published on Feb 28, 2016)

Singapore has a relatively good surveillance and monitoring system as dengue is a legally notifiable disease. Singapore has also in place a nation-wide dengue control program that combines all WHO-recommended control activities, that includes community education and participation, active breeding site detection exercises, fogging exercises and clinical surveillance systems (Struchiner et al., 2015). One of the main agencies involved in understanding these mosquito vectors better, is the National Environment Agency (NEA) of Singapore. NEA, together with its public health laboratory, the Environmental Health Institute (EHI), conducts research, surveillance and risk assessments while simultaneously having a vector control program in place that is three-pronged, incorporating source reduction, public health education and law enforcement.

As part of their research and surveillance, NEA uses active traps (e.g. Gravitraps and ovitraps) extensively to catch mosquitoes and collect data and in case of dengue cluster outbreaks, deploys staff to do house visits to check for stagnant water and possible breeding grounds. However, such monitoring methods and efforts are usually cost inefficient, time consuming and labour intensive (Kampen et al., 2015) and might not cover everywhere, especially in homes and clusters of private landed property (terrace houses, condominiums etc). In addition, not all mosquitoes would be attracted to the traps, resulting in some going unnoticed, especially those that breed in residential premises. As such, this presents an opportunity to increase the surveillance and control of mosquito vectors through a community-based approach of citizen science.

1.2 Citizen science networks for mosquitoes

Citizen science, as defined in the White Paper on Citizen Science for Europe, refers to the "general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources"³. Having a citizen-science approach can help to narrow the gap between professional scientists and the wider public and empower the general public with knowledge. Haklay (2013) formulated a framework (Figure 5) which illustrates the various levels of participation and engagement that a particular citizen science project can be at – starting at Level 1 "Crowdsourcing" where citizens only help in data collection to Level 4 "Extreme Citizen Science" where citizens collaborate with scientists to define, collect data and analyse data for a particular problem.

_

³ Sanz, F. S., Holocher-Ertl, T., Kieslinger, B., Garcia, F. S., & Silva, C. G. (2014). White Paper on citizen science for Europe. Retrieved June 10, 2017, from http://www.socientize.eu/sites/default/files/white-paper_0.pdf

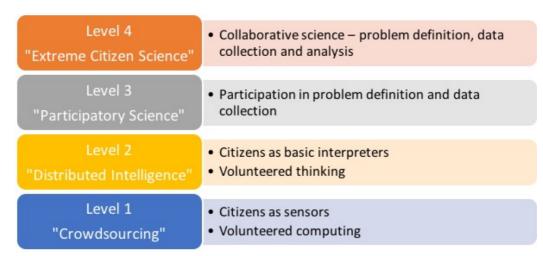


Figure 5 Levels of participation and engagement in Citizen Science projects (Adapted from Haklay, 2013)

Whatever the level of participation and engagement, this method of involving citizens to contribute to science has gained much traction and is becoming increasingly popular over the past few years. To date, there are about 6 European countries (*Muggenradar* in The Netherlands; *Mückenatlas* in Germany; *Mosquito Watch* in UK; *Mosquito Alert* in Spain; *iMoustique* in France; *MosquitoWEB* in Portugal) that have such passive monitoring and surveillance programs in place to monitor mosquitoes. The use of such a citizen-science approach in mosquito surveillance helps in identifying new populations, habitats, and distribution areas, as well as enable researchers to generate and study temporal activity trends of native and invasive species (Kampen et al., 2015).

1.2.1 Muggenradar in The Netherlands

One such citizen science initiative is the "Muggenradar" (mosquito radar; www.muggenradar.nl) in The Netherlands. This surveillance tool was first introduced in 2014 to investigate mosquito activity during winter. The Dutch public was addressed and asked to report mosquito nuisance through an online questionnaire and had the chance to submit the mosquito specimen for further identification. Since summer 2016, as part of the data collection efforts in Muggenradar, the public can visit the Muggenradar website⁴ and fill in the online form either with their own accounts or anonymously. Citizen scientists submitting mosquito nuisance reports will be required to report on the amount of nuisance experienced; the type of nuisance experienced (biting, buzzing etc.); when and where the nuisance was experienced; the amount of mosquitoes they encountered; the kinds of preventive measures they undertake to prevent mosquito nuisance; and other information such as date, location (latitude and longitude) is also recorded when the form is submitted online. With the submissions of mosquitoes from the public, the scientists behind this project were able to derive a map to show the relative distribution of the submitted mosquitoes. Genetic analyses on the submitted mosquito specimens are still ongoing, and these analyses will eventually result in a more detailed map of mosquito presence and nuisance. This information will provide insights into the ecology of the mosquito species in The Netherlands. The success of this initiative has been attributed to several aspects: (i) clear instructions given (for the submission of specimens); (ii) postage costs were covered; (iii) ease of completing the questionnaires; (iv) open communication with the public and (v) regular updates through the media and social media (Kampen et al., 2015). However, there has not been any analysis being carried out on the collected data thus far. This presents an opportunity to delve into the data to investigate the usefulness of a citizen-science approach.

_

⁴ Muggenradar.nl, Retrieved January 24, 2018, from https://www.naturetoday.com/en/nl/observations/mosquito-radar

1.2.2 Global Mosquito Alert

Furthermore, to back the usefulness of such a citizen-science approach towards mosquito surveillance, a new alliance of citizen-science organizations and UN Environment Programme (UNEP) was formed in April 2017, to coordinate efforts in the fight against mosquito-borne diseases. This new initiative, known as "Global Mosquito Alert" will be the first of such a global platform involving a citizen-science approach to monitor mosquito populations. This initiative will be a collaborated effort, which will involve established citizen science associations from Europe, Australia, America and the developing citizen science community in Asia. With such a platform, concerned citizens have an avenue to share their observations and information from the ground with scientists, which can supplement information already available from public health sources and enable scientists to monitor mosquito population trends in real time. Furthermore, pooling of resources, knowledge and information around the world, can help to better understand the mosquito vectors, predict outbreaks, and support public health management⁵.

1.3 Knowledge gap and problem statement

With the increasing global temperatures and Singapore in its role as being a transport hub, such conditions can be expected to facilitate the transportation of mosquitoes across borders and breeding of mosquito vectors and thus, increases the risk of mosquito-borne diseases in Singapore. In addition, given that the majority of breeding sites are found within residential premises, some gaps in mosquito surveillance exist (e.g. mosquitoes that breed within residential premises may go undetected by active traps placed in public spaces). This gap can potentially be bridged with a citizen-science approach and eventually contribute towards the 'Global Mosquito Alert'.

However, little is currently known about the (Singapore) public's perception towards mosquito-borne diseases, their current preventive behaviours and their willingness to participate in a citizen science project. The latter probably is due to people's lack of awareness of such approaches, busy lives and perhaps even their lack of interest. Thus there is a need to determine people's perception of mosquitoes and mosquito-borne diseases, and how receptive they would be to participate in a citizenscience approach.

1.4 Research objective, questions and relevance

1.4.1 Objective of project

This thesis project aims to investigate how the existing mosquito monitoring programs in Singapore can be extended with a citizen-science approach.

This thesis will contribute towards the vector-control department of Singapore's National Environment Agency, to provide a better understanding of how society perceives mosquito-borne diseases (such as dengue) and can be used in support of engaging the public in Singapore to help with data collection of mosquito surveillance and control.

1.4.2 Research questions

To help achieve the objective of the project, five research questions (RQs) have been formulated:

RQ1 How is the mosquito surveillance and control currently organized in Singapore?

RQ2 What factors explain preventive behaviour?

RQ3 How can citizens contribute in providing data to support mosquito and disease surveillance? How variable are the nuisance levels of mosquitoes reported by the public?

⁵ He, Y. (2017). Global Mosquito Alert: UN Backed Citizen Science Platform to Fight Mosquito-Borne Diseases | Wilson Center. Retrieved June 10, 2017, from https://www.wilsoncenter.org/blog-post/global-mosquito-alert-un-backed-citizen-science-platform-to-fight-mosquito-borne-0

RQ4 How do stakeholders perceive the potential contribution of citizens towards mosquito surveillance and control?

RQ5 What factors could influence active participation in citizen science projects?

1.4.3 Research relevance

This study will bridge the gap between science and society in Singapore by investigating how a citizenscience approach can be organized to supplement existing mosquito surveillance and control, while simultaneously educating the public on how to protect themselves from mosquito-borne diseases.

The societal relevance of this study is its local and international relevance. For the local (Singapore) society, this thesis will contribute to Singapore Government's efforts in mosquito surveillance and control by investigating public perception towards mosquito-borne diseases (e.g. if they think that this is a serious problem). Based on personal experience, the general public seems rather nonchalant about mosquito-borne diseases despite the outbreaks in previous years. By investigating public perception, it can help in future communication and educational strategies by governmental agencies. Furthermore, as there is a complex interplay of factors that can affect mosquito populations, having a citizen-science approach provides a platform for more data to be collected to supplement existing surveillance and control efforts (society to science) and for information transfer (science to society) to educate the public (in times of low outbreaks) and to inform the public (in case of an outbreak).

Internationally, this thesis can contribute towards the Global Mosquito Alert's coordinated efforts in mosquito surveillance and control. The pooling of resources and sharing of knowledge and information around the world can contribute towards a better understanding of the mosquito vectors and perhaps even predict outbreaks.

1.5 Outline of report

The rest of the report will be organized into eight different chapters. Chapter 2 presents the overview of the methodologies used for data collection and analysis. Chapter 3 will address RQ1 by describing the current mosquito surveillance and control efforts that are currently in place in Singapore. After having a better picture of the mosquito scene in Singapore, Chapter 4 will then look into the results of the survey. It will address RQ2 by investigating preventive behaviour amongst the residents in Singapore and the factors that drive such behaviour. Chapter 5 looks into the existing mosquito-related citizen science project, Muggenradar in the Netherlands. This case study of Muggenradar will address RQ3. Thereafter, Chapter 6 dives into the information gathered from interviews, to understand various stakeholders' perception towards a citizen-science approach, addressing RQ4. Chapter 7 will address RQ5 by using the results of the survey to assess factors that influence participation in citizen science projects. The results, its implications, and limitations will be discussed in Chapter 8. Finally, Chapter 9, will bring together the most important conclusions to answer the main objective of this research project, and to provide recommendations for the next steps.

2 Methodology for Data Collection and Analyses

In order to gather the information needed to answer the research questions listed in the previous chapter, a series of methodologies were chosen to achieve this. This chapter describes in detail how each of the methods were carried out to gather and analyse the data collected. Figure 6 depicts the respective data collection methods that were used to address the different research questions.

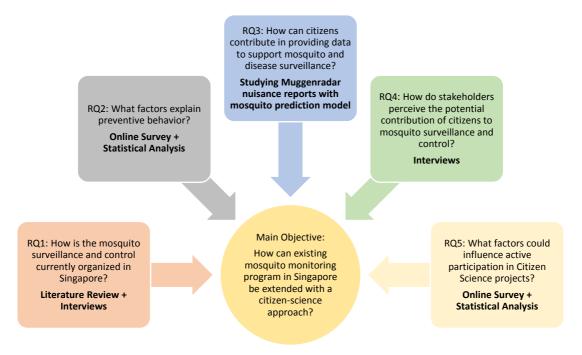


Figure 6. Framework to illustrate the methods used to answer the research questions

2.1 Literature review

A literature review was conducted to gather more in-depth information related to existing surveillance and control efforts in Singapore. Literature was also used to put my results in perspective and to understand the benefit and usefulness of citizen science contributions towards science. I searched the literature mainly from Wageningen University and Research's library database of journal articles as well as Google Scholar. The Google search engine was also used to find newspaper articles as well as look out for any information on public's opinion (e.g. blogposts, social media) towards mosquitoes in Singapore.

2.2 Interviews

In my research I interviewed various stakeholders on surveillance and control of mosquitoes in Singapore, as well as on what they know and think about applying a citizen-science approach to complement existing monitoring efforts in Singapore. In addition, conducting the interviews also provided some insight into the various stakeholder's interest in being a part of a citizen-science approach.

I selected the stakeholders and experts based on their background, appearances in press releases with regards to mosquitoes and mosquito-borne diseases and/or their involvement in the mosquito scene in Singapore. In total, I conducted seven interviews between July 2017 and August 2017. Information gathered from the literature review was used as a guide to help me draw up a general list of questions

for the interview. I also included some specific questions based on each interviewee's expertise and area of research. The list of interviewees and the interview questions can be found in Appendix A.

2.3 Online public perception survey

I performed an online survey to better understand people's perception towards mosquito-borne diseases in Singapore, the reasons behind people's (in)motivation to carry out preventive measures, as well as their willingness to contribute towards a mosquito citizen science project. This method of data collection was selected as I had limited time in Singapore to do face-to-face interviews. Furthermore, with an online survey (with a shareable link), more people can be reached within a short period of time and it maintains anonymity of respondents. I based the survey questions mostly on questions used in Potter, Jardine, & Neville's (2016) paper on "A survey of knowledge, attitudes, and practices in relation to mosquitoes and mosquito-borne disease in Western Australia" as well as existing studies⁶ with regards to mosquito-borne diseases. I constructed the survey with the Extended Parallel Processing Model (EPPM) as a basis for better understanding (see Section 3.3.1). A copy of the survey is attached in Appendix B.

2.3.1 Extended Parallel Processing Model

The EPPM is a fear appeal theory that can be used to understand individuals' reaction and response to health related messages or information deemed fearful or threatening (Witte & Allen, 2000). The EPPM predicts that if a health message invokes fear in individuals, it will cause the individual to react either with an adaptive response or a maladaptive response. The basis of EPPM, according to Witte, is that fear has the potential to impede behavioural change – the degree to which an individual feels threatened by a health issue determines his or her motivation to act, and the individual's confidence to effectively reduce or prevent or protect oneself determines the action itself.

There are four key variables in the EPPM, two related to perception of the threat and two related to the perception of efficacy. The 'threat' variables includes perceived severity and perceived susceptibility and the 'efficacy' variables includes response efficacy and self-efficacy. I designed the survey according to the variables in the EPPM. The definitions of the variables and examples of possible questions are illustrated in Table 1.

The EPPM predicts that the fear of a health risk, in this case mosquito-borne diseases, can result in either adaptive, self-protective actions or maladaptive, self-defeating actions. When an individual perceives a strong threat but has high efficacy beliefs, the model predicts that the individual will engage in 'danger control process" i.e. self-protective behaviour. However, when perceived threats are high but perceived efficacy is low, "fear control process" will be activated and this results in maladaptive denial or rejection of protective behaviours (Figure 7).

2.3.2 Data collection for survey

The research was set-up as a cross-sectional study, using a self-administered online survey with the online Qualtrics⁷ program. The survey invitation was spread through this author's personal network and social media accounts (e.g. Facebook, Instagram, Twitter, LinkedIn). The aim was to reach out to as many people living in Singapore as possible (goal of at least 100 respondents) and to gather respondents with varying backgrounds and age groups. The survey was opened to the public on 4th

⁶ Baseline Household Survey - Environmental virtual observatories for connective action in malaria control and prevention (Personal communication)

⁷ Qualtrics software enables users to collect and analyse data online for different purposes. Retrieved January 24, 2018, https://www.qualtrics.com

December 2017 and was closed on 15th December 2017 after receiving a substantial amount of respondents for data analysis.

Table 1. Definition of the variables in EPPM and examples of statements formulated in this project's public perception survey to assess the perceived threat levels and efficacy levels according to the EPPM

	Variables	Definition / Meaning	Examples of statements to assess the variable
Threat	Perceived Severity	The perception the individual has of the magnitude of the threat. (i.e. how serious I think the threat is)	"Dengue is a serious disease"; "I worry about contracting mosquito-borne diseases in Singapore"
Perceived Threat	Perceived Susceptibility	The perception the individual has of how likely the threat is to impact them. (i.e. how susceptible/vulnerable do I think I am with regards to the threat)	"I am vulnerable to mosquito-borne diseases"; "I am more likely to get Dengue than the people around me"
ed Efficacy	Response Efficacy	The perception the individual has that the action, if carried out, will successfully control the risk. (i.e. how effective I think the action is in protecting me from the threat)	"Using other recommended Dengue/Zika preventive measures will decrease my chances of getting infected with Dengue/Zika"; "The 5-step Mozzie Wipeout is effective to prevent mosquitoes from breeding in my house"
Perceived	Self-Efficacy	The perception the individual has that they are competent to perform the tasks needed to control the risk. (i.e. how confident I am in carrying out the action to prevent myself from the threat)	"I am confident that I can prevent myself from getting Dengue/Zika"; "I have enough information about how to protect myself and my family from Dengue/Zika"

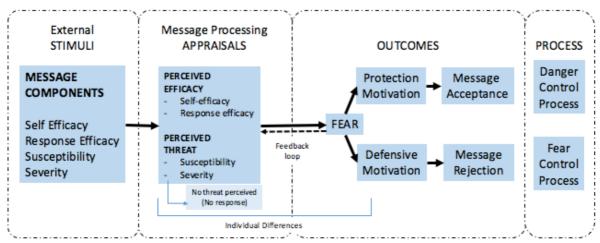


Figure 7. Concept map of EPPM (Adapted from: http://journals.sagepub.com/doi/pdf/10.1177/1090198111418108)

2.3.3 Data analysis of survey results

I used the Statistical Package for Social Sciences (SPSS, Version 23) program to analyse the data. Simple descriptive statistics were obtained to get a general feel of the responses (refer to Appendix B). Bivariate analyses and linear regressions were carried out to determine if there are any possible relationships between the various variables as explained by the EPPM.

To carry out the bivariate analyses and the linear regressions, first a score had to be calculated for each of the variables (perceived severity, perceived susceptibility, perceived self-efficacy, perceived response efficacy). For this, I recoded some of the output from the survey into different numbers for the scoring, to ensure that scores for each section were in the same direction. For example, under

'Perceived Severity', a high score would mean that the respondent's level of perceived severity is high. To do this, I analysed each of the statements and gave a score to ensure that it follows the logical flow and scoring "direction" for each section (Table 2). If a person strongly agrees with 'Dengue is a serious disease' it would be given a high score (5) as it would mean that perceived severity is high. However, if a respondent strongly agrees with 'I think the relevant agencies are doing a good job keeping mosquitoes at bay', it would mean that they have trust in the agencies and thus have a lower perceived severity, hence a low score (1) was given. The same logic was applied to the other statements under the different variables and the scoring is shown in the sample of survey attached (Appendix B).

Table 2. Example of scoring carried out for the various statements in each of the categories of the EPPM. The statements in this table are under "Perceived Severity"; a high score here would mean high perceived severity.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable
Dengue is a serious disease	1	2	3	4	5	-
Zika is a serious disease	1	2	3	4	5	-
I worry about contracting mosquito-borne diseases in Singapore	1	2	3	4	5	-
If I get dengue, it will not be more serious than other diseases	5	4	3	2	1	-
I think the Singapore healthcare system is well-equipped and able to treat mosquito-borne diseases	5	4	3	2	1	-
I think the relevant agencies are doing a good job keeping mosquitoes at bay	5	4	3	2	1	-

Following the recoding of the scoring, a mean score was calculated for each of the categories (of the EPPM variables) as well as for preventive measures for the bivariate analyses and linear regressions analyses. The mean was used instead of the sum as there was an option for the respondents to choose 'I don't know' or 'Not applicable', and using the sum would mean that these options were also factored in, which might not be an accurate representation. Hence, the options 'I don't know' and 'Not applicable' were recoded as missing values and the mean was used in calculation of the score for further analysis.

2.4 Mosquito nuisance reporting data

To obtain a better understanding how citizen science projects can contribute to the scientific world, there is a need to study existing citizen science projects. One such citizen science project involving mosquito (nuisance) reporting is the Muggenradar in The Netherlands (see *Chapter 1.2.1 Muggenradar in The Netherlands*)

The reports were extracted from Muggenradar and I analysed them using Microsoft Excel to explore the variations in reporting as well as the usefulness of a citizen science initiative. A nuisance score was given based on the type of nuisance experienced by the respondent (Table 3). Thereafter, the nuisance scores obtained were also compared with the results of a prediction model developed to forecast potential mosquito nuisance, using parameters such as temperature, wind speed and relative humidity which will be explained later in this section.

Table 3. Nuisance score given for the varying nuisance experienced as reported on Muggenradar

Nuisance Reported	Nuisance Score
"Geen overlast" (No nuisance)	1
"Een beetje overlast" (Some nuisance)	2
"Veel overlast" (Much nuisance)	3
"Heel veel overlast" (Very much nuisance)	4

Besides having the Muggenradar data, to determine how and whether voluntary citizen reporting is of any significant contribution to science, there is a need to compare it against other data. However, since it is not possible to know the actual amount of nuisance by mosquitoes in The Netherlands, it can only be compared to the results as predicted by a model.

A previous MSc thesis project (Oosterbroek, 2011) which was a part of the Insect Weather Forecast Project⁸, developed a model to predict mosquito nuisance in the Netherlands. The prediction model included meteorological parameters such as air temperature, humidity, precipitation, wind velocity and visibility. Following the results of his project as well as expert judgement by the Muggenradar team, a scoring matrix was developed to calculate the predicted mosquito nuisance score based on meteorological parameters (Table 4). In order to calculate the (predicted) score of mosquito nuisance, climate data was retrieved from the Royal Dutch Meteorological Institute (KNMI) for the period of January 2016 to December 2017.

Table 4. Scoring matrix developed to predict mosquito nuisance score in The Netherlands based on weather parameters.

Parameter	Unit	Score								
Parameter	Unit	0	1	2	3					
Average wind speed	Km/hour	> 11	7 < X ≤ 11	3 ≤ X ≤ 7	X < 3					
Minimum temperature	°C	< 4	4 ≤ X ≤ 8	8 < X ≤ 12	>12					
Maximum temperature	°C	< 10	10 ≤ X ≤ 15	15 < X ≤ 20	>20					
Total precipitation	mm	≥ 10	2 ≤ X < 10	0.0001 ≤ X < 2	X ≤ 0					
Minimum humidity	%	≤ 50	50 < X ≤ 65	65 < X ≤ 75	>75					

The mosquito nuisance score was calculated and tabulated in Microsoft Excel. Thereafter, the score was used to compare it against the nuisance score derived from Muggenradar data. The scores for the model prediction range between 0 to 15 and the nuisance score from Muggenradar reports range between 1 to 4. This method provided the opportunity to study the variances and trends between reported mosquito nuisance and calculated mosquito nuisance and serves as a way to validate the model as suggested by Oosterbroek (2011) in his final report.

19

⁸ Insect Weather Forecast Project was a collaboration between the Environmental Systems Analysis Group (within the Nature's Calendar Project), the Laboratory of Entomology, research institute Alterra and the management of the weather forecast television program of Piet Paulusma. It was started with the goal of predicting insect activity for the coming days in The Netherlands, with emphasis on mosquitoes.

3 Mosquito Scene in Singapore

3.1 Introduction to the dengue surveillance and mosquito scene in Singapore

Dengue is endemic in Singapore and has posed as a public health challenge since the first case of dengue reported in the 1960s. Thereafter, a Vector Control Unit was set up under the Ministry of Health's Quarantine and Epidemiology Branch, marking the start of public health response to dengue. In 1972, the Vector Control Unit was transferred to the purview of the then Ministry of Environment (now known as Ministry of Environment and Water Resources) after dengue was made a notifiable disease (Ooi, Goh, & Gubler, 2006). Since then, an integrated surveillance framework exists to support decision making and enhance the agencies' situation awareness for targeted interventions with regards to vector-borne diseases in Singapore, in particular dengue (Figure 8).

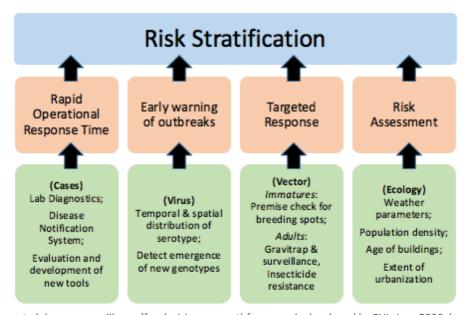


Figure 8. Integrated dengue surveillance (for decision support) framework, developed by EHI since 2006, has four pillars of surveillance, namely case surveillance, virus surveillance, vector surveillance and ecology surveillance. (Adapted from: http://www.nea.gov.sg/public-health/environmental-public-health-research/surveillance-and-epidemiology-programme)

The alert system for dengue outbreaks was developed by the EHI, and it is based on the circulation of dengue virus serotypes. There are four pillars of surveillance in this alert system (Figure 8) — case surveillance involving the Ministry of Health (MOH); virus surveillance (involving primary healthcare clinics); vector surveillance (by NEA); and ecological surveillance.

As part of the dengue surveillance, the NEA has a series of surveillance programmes (e.g. vector surveillance) that enables them to study and monitor vector populations and the emergence of vector-borne diseases. The programmes provide insights into transmission trends so that the proper preventive and control measures can be implemented effectively to lessen the impact of disease outbreaks⁹.

Other than vector surveillance programmes, Singapore also has a dengue control program that effectively combines all WHO-recommended control activities such as public health education, community engagement and participation, environmental management as well as a clinical

⁹ NEA: Overview of Vector Control. (n.d.). Retrieved March 12, 2018, from http://www.nea.gov.sg/public-health/vector-control/overview

surveillance system (Struchiner et al., 2015). The dengue control program is spearheaded by the National Environment Agency (NEA), a statutory board under the Ministry of Environment and Water Resources (MEWR). The NEA implements and manages the vector control aspect of dengue, as well as inter-ministry collaborations, public-private cooperation as well as community engagement and involvement (Yoshikawa, 2013). This is part of the NEA's "3P" partnership which connects People (volunteers and grassroots), the Private sector (service providers and professional associations) as well as the Public sector (governmental agencies & statutory boards) and examples of this 3P partnership can be seen in the activities that NEA carries out with regards to vector control (Yoshikawa, 2013), which will be further elaborated in this chapter.

As this research project is mainly focused on vector surveillance and control of mosquitoes in Singapore, this chapter will show in greater detail how the current mosquito surveillance and control is being organized in Singapore, with the findings obtained from literature reviews, internet searches as well as interviews with key stakeholders involved, to answer RQ1.

3.2 Mosquito surveillance

As 85% of the Singapore population lives in high-rise buildings, this high level of urbanization and population density means that a lot of people are in close proximity to their neighbours and has the possibility to result in regular dengue outbreaks (Liew & Curtis, 2004). As a result, there is a need for a surveillance programme to monitor the mosquitoes. The NEA, together with the EHI, both work on the surveillance of mosquitoes as part of their vector control program. The surveillance, which will be elaborated in this section, includes the use of Gravitraps, house visit by NEA officers as well as research into vector resistance towards insecticides, enables the agency to have a better understanding of the mosquito vectors and transmission trends. With a better understanding, it will enable agencies involved to implement the appropriate preventive and control measures to manage the mosquitoes in Singapore.

3.2.1 Gravitraps

For the longest time, dengue surveillance and control programs were always challenged by the lack of resources as well as cost-effective tools that could trap adult *Aedes* mosquitoes to provide an indication of their population in the environment (Lee et al., 2013). However, in 2013, NEA developed and introduced Gravitraps (Figure 9A), a cost-effective tool designed to attract and trap gravid female *Aedes* mosquitoes. Gravitraps works on the basis of exploiting the skip-oviposition ways of female *Aedes aegypti* when they distribute their eggs in different containers to increase survival rate of their offsprings. The design of Gravitraps took into consideration the fact that *Aedes aegypti* mosquitoes lays its eggs in water containing organic material in containers, and have a higher preference for dark coloured containers that are shaded ¹⁰.

The Gravitrap is a black container which contains 10% hay infusion water, a wire mesh layer, as well as a sticky inner surface (Figure 9B). The hay infused water provides a conducive environment which attracts the gravid female mosquito; the sticky inner surface is to trap the female *Aedes* mosquito once it has laid its eggs (Figure 9A); and the wire mesh layer serves as an additional protection to prevent the offspring from escaping if it develops into an adult mosquito. (Lee et al., 2013)

¹⁰ Dengue and the *Aedes aegypti* mosquito. (n.d.). Retrieved March 12, 2018, from https://www.cdc.gov/dengue/resources/30jan2012/aegyptifactsheet.pdf

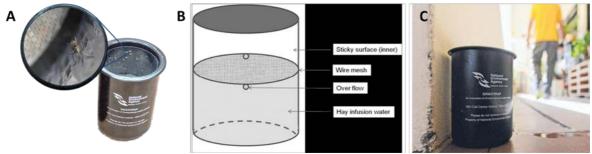


Figure 9. Picture of Gravitrap (A) developed by NEA; a schematic design (B) of the Gravitrap and a photo (C) of a Gravitrap placed along a corridor of a HDB flat. (Retrieved from (A) NEA; (B) Lee et al.; (C) https://www.todayonline.com/singapore/over-10000-breeding-sites-destroyed-jan-july)

The NEA manages the set-up and monitoring of Gravitraps along the corridors of the public high-rise housing (known locally as HDB flats) (Figure 9C), apartments and backyards of landed homes. The use of Gravitraps has enabled the NEA to trap adult female *Aedes* mosquitoes, provide rough estimates of the *Aedes* population in various locations, and doubles as an evaluation tool to assess the effectiveness of control measures being undertaken. Till date there are around 50,000 Gravitraps deployed around Singapore and are checked and maintained weekly by NEA officers (Personal communication, Dr Christina Liew, 23 August 2017).

3.2.2 NEA officers conducting house visits

As dengue is part of the Singapore picture that does not seem to go away, the NEA stepped up their surveillance measures. As part of their surveillance and control strategy, NEA officers are deployed to the ground to conduct house visits to inspect residential premises for signs of mosquito breeding.

For example, when a dengue cluster has been detected, the NEA officers will be tasked to inspect all the homes in the surrounding areas of the dengue cluster. If, after several repeated attempts, the officers are still unable to reach owners of a home, the Control of Vectors and Pesticides Act (CVPA) in place, grants officers entry into these homes with the help of a locksmith. This is done under the supervision of senior officers in NEA as well as Town Council representatives. This Act ensures that homes, both vacant and occupied, does not become breeding grounds for mosquitoes, which can endanger the lives of those living nearby¹¹.

In addition to the house visits and the CVPA, there are also other enforcements in place. As of 14 March 2016, if residential homes are found to have mosquitoes breeding in their homes, they will be fined SGD200 (Singapore Dollars), regardless whether the residential unit is within a dengue cluster or not¹².

3.2.3 Laboratory and field research

In addition to the inspection that NEA carries out, they also have a research department that conducts applied research, in both field and laboratory, to have a better insight of vector-borne diseases such as mosquito-borne diseases as it is a threat to public health in Singapore. They also research into developing tools for management of these vectors responsible for the diseases. Some of their research includes: geographic information system for tracking vector distribution; dynamics of vector

¹¹ Is NEA really breaking into our homes to do dengue checks? (2013, May). Retrieved February 11, 2018, from https://www.gov.sg/factually/content/is-nea-really-breaking-into-our-homes-to-do-dengue-checks

¹² Hassan, N. J. (2016, February 28). S\$200 fine for homes found breeding mosquitoes from Mar 14. Retrieved February 12, 2018, from https://www.channelnewsasia.com/news/singapore/s-200-fine-for-homes-found-breeding-mosquitoes-from-mar-14-8167660

populations in disease outbreaks; diagnostic tools for monitoring insecticide resistance; evaluation and resistance management of insecticides; epidemiological studies of diseases; and evaluation of novel mosquito control tools (e.g. Project *Wolbachia*, to reduce *Aedes aegypti* populations)¹³.

3.3 Mosquito Control

With the surveillance programs in place, NEA and EHI have a better insight of the mosquito vectors and their transmission trends. Equipped with these insights and understandings, they are better able to introduce various preventive and control measures as part of the vector control programme. Vector control is defined as "the destruction, or the prevention of propagation or harbouring of vectors" (Yoshikawa, 2013). Acknowledging that vector control cannot be done single-handedly, the NEA's "3P" partnerships come into play, which involves inter-ministry collaborations, the private sector as well as the community at large. This section will describe in greater detail the mosquito control programmes that NEA has in place i.e. Project *Wolbachia*, Dengue Prevention Volunteer Group (DPVG), community outreach and public education, as well as mobile phone applications.

3.3.1 Project Wolbachia

As part of their vector control program, the EHI has been regularly exploring novel mosquito control methods to help alleviate the dengue problem in Singapore and has since focused on the *Wolbachia* technology since 2012¹⁴. They have since tested the technology in their laboratories and in 2016, carried out a 6-month small-scale study in the field¹⁵. Project *Wolbachia*, which uses the naturally-occurring *Wolbachia* bacterium, is a mosquito suppression strategy. The *Wolbachia* bacterium is first injected into the *Aedes aegypti* eggs; thereafter, the resultant pupae (with the *Wolbachia* bacterium) are sorted according to gender. The male *Wolbachia-Aedes aegypti* are selected and released to the environment. When these male *Aedes aegypti* mosquitoes, carrying the *Wolbachia* bacterium, mates with female *Aedes aegypti* without *Wolbachia*, their resulting eggs do not hatch as such pairings are biologically incompatible. Thus, overtime, this approach will lead to a decline in the *Aedes aegypti* population and contributes greatly towards vector control¹⁶.

3.3.2 Fogging and use of insecticides

As part of their vector control program, the NEA also routinely carries out vector control operations to remove mosquito breeding habitats. These operations include spraying insecticides indoors, carrying out fogging outdoors to kill adult mosquitoes, as well as oiling stagnant water in drains to kill mosquito larvae. The NEA also has a list of private pest control operators to carry out fogging and spraying of insecticides. These private pest control operators have to be registered officially with NEA as Vector Control Operators (VCOs) in order to be engaged conduct vector treatment or activity. In addition to being approved by NEA, these private pest control companies are given a set of guidelines as stipulated by NEA with regards to fogging and the use of insecticides. Dr Tony Teo, Director of Environmental Public Health Operations at National Environment Agency mentioned in The Straits Times, that these guidelines include that "fogging should be carried out in the earlier part of the

¹³ NEA (n.d.). Surveillance and Epidemiology Programme. Retrieved February 1, 2018, from http://www.nea.gov.sg/public-health/environmental-public-health-research/surveillance-and-epidemiology-programme

¹⁴ NEA (n.d.). Project Wolbachia – Singapore. Retrieved February 1, 2018, from http://www.nea.gov.sg/public-health/environmental-public-health-research/wolbachia-technology/project-wolbachia-singapore

¹⁵ Lim, V. (2017, February 8). Wolbachia-carrying mosquito study yields 'valuable' data: NEA. Retrieved February 1, 2018, from https://www.channelnewsasia.com/news/singapore/wolbachia-carrying-mosquito-study-yields-valuable-data-nea-7627930

¹⁶ NEA (n.d.). Wolbachia-Aedes Mosquito Suppression Strategy: How It Works. Retrieved February 1, 2018, from http://www.nea.gov.sg/public-health/environmental-public-health-research/wolbachia-technology/wolbachia-aedes-mosquito-suppression-strategy-how-it-works

morning or later part of the afternoon" as ambient temperatures are much lower then and allows for the fog to stay at ground level longer¹⁷.

3.3.3 Dengue Prevention Volunteer Group (DPVG)

Recognising that they do not have enough manpower to reach out to everyone in the shortest possible time, a joint initiative was formed between NEA and MEWR. The Dengue Prevention Volunteer Group (DPVG) was formed in 1998 to engage the community by providing them a platform to learn more about dengue prevention as well as to volunteer to spread the word about dengue prevention (Tan, Lee, & Tan, 2009). Volunteers are trained to recognise dengue symptoms, spot potential breeding spots, and know examples of appropriate preventive behaviour. Equipped with the appropriate knowledge and training, these volunteers then go door-to-door in housing estates help raise their neighbours and fellow residents' awareness of the severity of dengue as well as how to protect themselves and keep the neighbourhood mosquito-free (Figure 10A). Till date, the grassroots organizations under the People's Association (PA) have joined forces with the DPVG and there are currently more than 2000 dengue prevention volunteers helping to spread the word (Figure 10B)¹⁸.



Figure 10. (A) Photo of Mr Lim Kee Cheng and his son, Cleon Lim, both Dengue Prevention Volunteers, doing a house visit to educate their fellow residents on dengue prevention; (B) Poster depicting Dengue Prevention Volunteers as Dengue Fighters, as well as having the 5-Step Mozzie Wipeout to remind the community to stay vigilant and remove potential mosquito breeding spots in and around their homes. (Retrieved from NEA)

3.3.4 Community outreach, public education and the '5-Step Mozzie Wipeout'

As source reduction is central to Singapore's vector control efforts, the NEA recognises that a large effort will be needed on the community's part as it is not possible for NEA to cover the entire Singapore by themselves. Furthermore, as surveillance data has highlighted, a large proportion of mosquito breeding spots are found in residential premises. As such, the NEA has a "prescribed" preventive behaviour for the community to adopt. In April 2013, NEA launched the 'Do the Mozzie Wipeout' campaign with a focus on improving the community's awareness of dengue and encouraging them to take steps (e.g. 5-Step Mozzie Wipeout) to prevent mosquitoes from breeding in their homes 19. The 5-Step Mozzie Wipeout consists of a series of steps to check and remove stagnant water in homes, such as, turning pails upside down, changing the water in vases, clearing the excess water

¹⁷ Teo, T. (2016, September 28). Pest control operators advised on best times for fogging. Retrieved February 1, 2018, from http://www.straitstimes.com/forum/letters-in-print/pest-control-operators-advised-on-best-times-for-fogging

¹⁸ Poh, I. (2013, June 29). Anti-dengue efforts to be stepped up with 10,000 new volunteers. Retrieved February 1, 2018, from http://www.straitstimes.com/singapore/anti-dengue-efforts-to-be-stepped-up-with-10000-new-volunteers

¹⁹ NEA (n.d.). Do the Mozzie Wipeout Campaign. Retrieved February 1, 2018, from http://www.nea.gov.sg/events-programmes/campaigns/do-the-mozzie-wipeout-campaign

in flower pot plates etc (Figure 11A). The 'Do the Mozzie Wipeout' campaign is launched annually, usually when the number of dengue cases are expected to rise, and is supported by local Grassroots Advisers as well as the mobilisation of grassroots leaders and Dengue Prevention Volunteers (Figure 11B). Together with the campaign, house visits are carried out by DPVG; roadshows are held at various parts of Singapore with interesting activities for the whole family to participate in; and there would also be banners (Figure 11C) and publicity materials distributed to remind the community to stay vigilant and do the Mozzie Wipeout. In addition to the '5-Step Mozzie Wipeout', NEA also advises applying insect repellent on skin and wearing long-sleeved shirts and pants to keep mosquitoes away and reduce the potential for mosquito bites.



Figure 11. (A) The 5-Step Mozzie Wipeout banner showing the steps to carry out this "prescribed" preventive behaviour; (B)

The launch of the "Do the Mozzie Wipeout Campaign" in 2016 by NEA, its community partners and the Minister of
Environment and Water Resources, Dr Masagoes; (C) Publicity banners that are placed in public spaces to remind the
community to play their part in preventing dengue. (Retrieved from: (A) NEA; (B) The Straits Times; (C) NEA)

3.3.5 Mobile phone applications

While the previous examples mostly involve information dissemination and top-down approaches, mosquito control efforts in Singapore is not merely a one-way street. It was during my interview with Dr Alex Cook that I came to learn that there were mobile phone applications by NEA and the Municipal Services Office (MSO) that were developed for the public to report mosquito breeding spots to the relevant agencies (Personal communication, 26 July 2017).

myENV by NEA

The NEA first introduced the myENV app in 2011, and in 2014 released an updated version²⁰ (Figure 12), which contains information related to NEA's purview such as weather and environment. Users can receive real-time information on PSI (air quality), weather as well as dengue hotspots, and can also feedback on issues such as litter or construction noise and even mosquito breeding and nuisance to NEA²¹.

²⁰ Salim, Z. (2014, August 19). NEA rolls out updates for its myENV mobile app. Retrieved February 1, 2018, from https://www.cio-asia.com/tech/industries/nea-rolls-out-updates-for-its-myenv-mobile-app/

²¹ Walkthrough of NEA's myENV app. (2014, August 17). Retrieved January 31, 2018, from https://www.todayonline.com/videos/walkthrough-neas-myenv-app

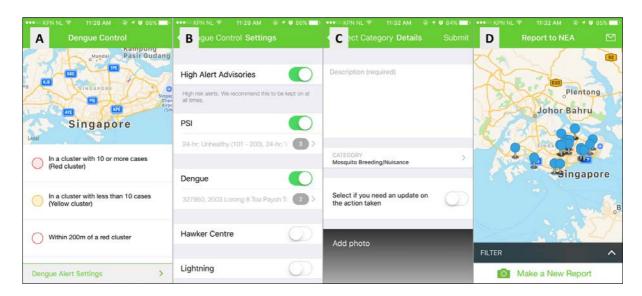


Figure 12. Screenshots from the myENV mobile phone application on an iOS device. When users click on "Dengue Control" they will be redirected to see a map of Singapore that will show (any) current dengue clusters (A); users can also set alerts for dengue clusters around the address they input (B); users will be asked to give descriptions (photos are optional) when they want to feedback on mosquito breeding/nuisance (C); users can also see an overview of feedback given by others (D). (Images are taken from personal mobile phone)

OneService by MSO

In 2015, the Municipal Services Office (MSO) launched the OneService mobile app, a one-stop platform for the public to provide feedback on municipal problems without having to search for the proper channels to reach the government agency or town council responsible. This comes as part of their plan to improve inter-government agency cooperation on municipal issues.²² The OneService app includes a segment where feedback can be given with regards to mosquito breeding grounds (Figure 13).

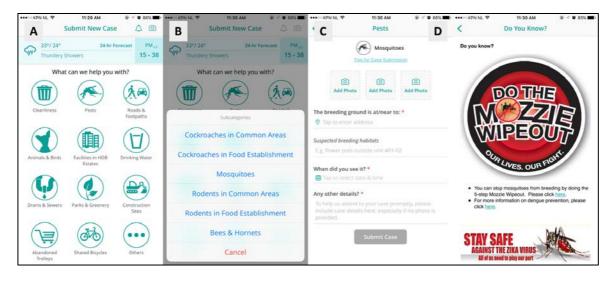


Figure 13. Screenshots from the OneService mobile phone application on an iOS device. Users can report anything from cleanliness to pests to abandoned trolleys (A); users can feedback on different types of pests (B); to report on mosquitoes, users have to state where the breeding ground is at (photos are optional (C); there is also additional information made available to the user with regards to the issue that they are reporting, in this case, more information about the Mozzie Wipeout is given (D). (Images are taken from personal mobile phone)

²² MSO (n.d.). About OneService. Retrieved January 31, 2018, from https://www.mnd.gov.sg/mso/mobile-about.htm

Mozzie Watch Keeper @ North West

The Mozzie Watch Keeper, jointly developed by North West Community Development Council (CDC), Holland Bukit-Panjang Town Council and the National Environment Agency (NEA), was launched on 24 May 2016. The motivation behind the app was to create an interactive mobile app for the community to learn more about as well as to spot and report cases of potential mosquito breeding grounds. Similar to myENV and OneService, Mozzie Watch Keeper @ North West has a segment which enables users to take photos of potential mosquito breeding grounds and feedback to NEA through the app. It also has an e-learning segment that allows users to learn more about mosquito-borne diseases as well as effective prevention methods²³. However, at the time of writing this report, the app could not be found in the Apple App Store.

-

²³ Goh, T. (2016, May 24). New app launched in the fight against dengue and Zika. Retrieved January 31, 2018, from http://www.straitstimes.com/singapore/health/new-app-launched-in-the-fight-against-dengue-and-zika

4 Preventive Behaviour of Residents in Singapore

Preventive (health) behaviour is "any activity undertaken by an individual who believes himself to be healthy for the purpose of preventing or detecting illness in an asymptomatic state" (Kasl & Cobb, 1966, p.246). Based on my personal observations and preventive behaviours listed in other papers, there are a variety of preventive behaviours that people can use to keep mosquitoes away and protect oneself from getting bites. Some of these behaviours include using the air-conditioning or fan; limiting outdoor activity during peak mosquito biting times, burning mosquito coil etc, and have been included in the survey for further analysis. The results of the online survey are used in this chapter to address RQ2 to find out what factors influence preventive behaviour amongst residents in Singapore.

4.1 Respondent characteristics

In total, 434 online surveys were open and of which 319 were completed and these 319 respondents were included in the analysis. Of that total, 188 were female (58.9%) and the mean age of the respondents was 35.6 years (SD = 13.8), with the respondents ranging between 16 and 81 years. Most participants (68.7%) had at least a tertiary education degree, and 12.9% had a polytechnic diploma while 11.2% did not have anything higher than a secondary education. 76.5% of the respondents were working professionals, while the rest were either students (11.6%), housewives/househusbands (2.2%) and unemployed (2.8%) or retired (6.6%). The survey together with the collated responses can be found in Appendix B.

4.2 Preventive measures taken by residents in Singapore

There are many different preventive measures available that people can adopt to keep their homes mosquito free and themselves from getting bitten. As such, my survey included a question to find out which of the various measures were more commonly used. Table 5 shows the results of that analysis, with the preventive behaviours ranked according to how often they are being carried out based on the mean of the total score. The top five preventive measures were: (1) eliminating standing water containers; (2) use of air-conditioning/fan; (3) covering water storage; (4) 5-Step Mozzie Wipeout; and (5) using insect repellent on skin. Of the list of preventive measures included in the survey, 'sleeping under mosquito bed net' recorded the lowest score in the frequency of use.

Table 5. Preventive measures ranked according to how frequent respondents carry out the various preventive measures, by using the mean of the total score based on respondents' choice; "Yes, often" = 3, "Yes, sometimes" = 2, "No, seldom" = 1, "No, never" = 0, "Not applicable" = missing value.

		N	Min.	Max.	Sum	Mean	Std. Deviation
1	Eliminating standing water containers	311	0	3	816	2.62	.61
2	Use the air-conditioning/fan	314	0	3	803	2.56	.70
3	Covering water storage	304	0	3	718	2.36	.86
4	5-step Mozzie Wipeout	305	0	3	517	1.70	.96
5	Using insect repellent on skin	318	0	3	539	1.69	.84
6	Wearing protective, long sleeved clothing	315	0	3	369	1.17	.90
7	Limiting outdoor activity during peak mosquito biting times	304	0	3	332	1.09	1.00
8	Burn mosquito coils	307	0	3	223	.73	.86
9	Use an electronic bug/insect zapper	308	0	3	210	.68	.86
10	Installing insect screens on windows/doors	297	0	3	166	.56	.90
11	Sleeping under mosquito bed net	298	0	3	82	.28	.64

Following the results of ranking, a simple bivariate analysis was carried out to test for correlations between the various preventive measures. The results of this analysis is shown in Table 6. For all the bivariate analysis tables in this report, the colour gradient indicates the level of significance – the

darker shade represents the significance level at p < 0.01; the lighter shade represents the significance level at p < 0.05; and no shading represents no significance.

From Table 6, it can be observed that there are significant correlations between various variables. All the significant correlations were positive and the strongest one being 'Eliminating standing water containers' with 'Covering water storage' (r=.567, p<0.01). Some of these correlations were expected, i.e. significant correlation between 'Eliminating standing water containers' (r=.278, p<0.01) and 'Covering water storage' (r=.282, p<0.01) with '5-Step Mozzie Wipeout', which can help with the consistency and reliability of the results from the survey. It can also be observed that all the preventive measures are not being carried out singly, but always with another preventive measure, evident in Table 6 where each row has at least one coloured box, signifying that there is a significant relationship with at least one other preventive measure.

Table 6. Pearson correlations between preventive measures arranged in order of most-used to least used, based on the mean of the total score for each of the respective preventive measures (Table 5).

	2	3	4	5	6	7	8	9	10	11
1-Eliminating standing water containers	.240**	.567**	.278**	.047	.013	.104	003	.016	004	001
2- Use air-conditioning or fan	-	.235**	.179**	.085	.035	.172**	.038	.042	.015	050
3-Covering water storage		-	.282**	.172**	.078	.066	.097	.034	.049	.018
4-5-Step Mozzie Wipeout			-	.128*	.159**	.147*	.062	.085	.180**	.030
5-Using insect repellent on skin				-	.285**	.196**	.160**	.283**	.140*	.220**
6-Wear protective, long- sleeved clothing					-	.337**	.163**	.157**	.165**	.237**
7-Limiting outdoor activity during peak mosquito biting times						-	.116*	.182**	.318**	.284**
8-Burn Mosquito Coil							-	.162**	.222**	.312**
9-Use an electronic bug/insect zapper								-	.305**	.278**
10-Installing insect screens on windows/doors									-	.380**
11-Sleeping under mosquito bed net										-
** p < 0.01, * p < 0.05										

4.3 Factors that influence preventive behaviour

In order to have a better understanding of the underlying reasons and factors behind people's motivation to carry out preventive behaviour, I carried out more bivariate analyses to test if there were any significant relationship(s) between various questions in the survey.

Firstly, the various categories as stipulated by the Extended Parallel Process Model (EPPM), namely the perception of severity, susceptibility, self-efficacy and response efficacy were tested against each other, as well as with experience and the overall preventive measure score. The results of this bivariate analysis are shown in Table 7. Based on the results of this bivariate analysis, it is observed that all the significant correlations were positive. The strongest correlation was that between 'Perceived Self-Efficacy' and 'Perceived Response Efficacy' (r=.154, p<0.01), followed closely behind by 'Perceived Severity' and 'Perceived Susceptibility' (r=.151, p<0.01). there were also correlations between 'Perceived Susceptibility' with 'Perceived Response Efficacy' (r=.142, p<0.05) and with 'Experience with Mosquito-Borne Diseases' (r=.120, p<0.05).

Table 7. Pearson correlations between preventive measures and experience with the variables as postulated by the EPPM. The colour gradient indicates the level of significance – the darker shade represents the significance level at p < 0.01; the lighter shade represents the significance level at p < 0.05; and no shading represents no significance.

	Perceived Severity	Perceived Susceptibility	Perceived Self-Efficacy	Perceived Response Efficacy	Experience with MBD
Preventive Measure	009	.056	.023	054	.030
Perceived Severity	-	.151**	071	.028	.026
Perceived Susceptibility		-	.041	.142*	.120*
Perceived Self Efficacy			-	.154**	009
Perceived Response Efficacy				-	052
Experience with MBD					-

^{**} p < 0.01, * p < 0.05

Preventive Measures against EPPM Variables & Experience

Next, to better understand what influences preventive behaviour, a further analysis was done to look at each preventive measure individually and carry out a bivariate analysis with the various categories. The results of this bivariate analysis is shown in Table 8. Based on the results of this bivariate analysis, it was observed that half of the significant correlations were positive and the other half was negative. The strongest correlation was between '5-Step Mozzie Wipeout' and 'Perceived Self-efficacy' (r=.194, p<0.01), followed closely behind by 'Sleeping under mosquito bed net' and 'Perceived Severity' (r=.174, p<0.01). The weakest correlations were between 'Using insect repellent on skin' with 'Perceived Susceptibility' (r=.116, p<0.05) and 'Using the air-conditioning or fan' with 'Perceived Severity' (r=.123, p<0.05).

Table 8.Pearson correlations between the various preventive measures and the total score for the different variables as postulated in the EPPM. The total score for each variable is computed by taking the sum of the responses for a series of statements under each category.

	Perceived Severity	Perceived Susceptibility	Perceived Self-Efficacy	Perceived Response Efficacy	Experience with MBD
Eliminating standing water containers	.098	.010	.104	005	.051
Use the air-conditioning or fan	.123*	018	.043	010	042
Covering water storage	.095	.041	.111	041	.045
5 Step Mozzie Wipeout	.092	004	.194**	.013	.092
Using insect repellent on skin	.026	.116*	122*	040	001
Wear protective, long sleeved clothing	127*	036	045	019	056
Limiting outdoor activity during peak mosquito biting times	049	.059	.008	.044	019
Burn mosquito coils	.029	.021	009	046	078
Use an electronic bug/insect zapper	042	.096	080	023	.154**
Installing insect screens on windows/doors	089	.050	.013	085	.083
Sleeping under mosquito bed net	174**	.140*	128 [*]	149**	082

^{**} p < 0.01, * p < 0.05

I noticed that more significant correlations arise when preventive measures were tested individually. I therefore decided to go another step deeper into the (bivariate) analyses. The various preventive measures were put against the individual statements under each category of 'perceived severity', 'perceived susceptibility', 'perceived self-efficacy' and 'perceived response efficacy' and the results are shown in Tables 9, 10, 11 and 12 respectively.

Preventive Measures against Perceived Severity

Table 9 shows that a handful of significant correlations were observed and that most of them correlated negatively. The strongest correlation was that between 'Sleeping under the mosquito bed net' and 'Dengue is a serious disease' (r=-.185, p<0.01), followed by 'Wear protective, long sleeved clothing' with 'Zika is a serious disease' (r=-.159, p<0.01). However, it should be noted that these

correlations were negative, meaning that the direction of the correlation corresponds to a decreasing relationship. The weakest correlations observed were between 'Wear protective, long-sleeved clothing' with 'Dengue is a serious disease' (r=-.112, p<0.05), followed by 'Using insect repellent on skin' with 'I worry about contracting mosquito-borne diseases in Singapore' (r=.115, p<0.05).

Table 9. Pearson correlations between the various preventive measures and the statements under the category of "Perceived Severity".

						I think the Singapore healthcare system is	I think the
			I worry about	If I get		well-	relevant
			contracting mosquito-	Dengue, it will not be	I get Zika, it will not be	equipped and able to treat	agencies are doing a good
	Dengue is a	Zika is a	borne	more serious	more serious	mosquito-	job keeping
	serious	serious	diseases in	than other	than other	borne	mosquitoes
	disease	disease	Singapore	diseases	diseases	diseases	away
Eliminating standing water containers	.083	.038	.062	096	092	.018	015
Use air-conditioning or fan	028	.063	.108	101	067	063	081
Covering water storage	.037	.050	.047	098	042	010	055
5-Step Mozzie Wipeout	.087	.071	.117*	046	.098	003	039
Using insect repellent on skin	008	.038	.115*	.005	022	035	047
Wear protective, long-sleeved clothing	112*	159**	043	.055	.061	106	078
Limiting outdoor activity during peak mosquito biting times	131*	097	.078	.044	.040	079	119*
Burn Mosquito Coil	071	069	.046	042	028	043	126*
Use an electronic bug/insect zapper	048	071	.089	.030	.059	045	078
Installing insect screens on windows/doors	061	110	.001	.041	.101	009	009
Sleeping under mosquito bed net	185**	170**	109	006	.013	119*	064

^{**} p < 0.01, * p < 0.05

Preventive Measures against Perceived Susceptibility

Next, the preventive measures were tested against the statements under 'perceived susceptibility' and the results are shown in Table 10. Based on the results, there were a handful of significant correlations, half of which were positive and the other half were negative. The strongest correlation was that between 'Sleeping under mosquito bed net' and 'I am more likely to get dengue than the people around me.' (r= .207, p<0.01), followed closely behind with 'Using insect repellent on skin' with the same statement (r= .197, p<0.01). The weakest correlation observed was that between 'Installing insect screens on windows/doors' and 'I am exposed to *Aedes* mosquitoes' (r=-.134, p<0.05), followed closely by 'Burn mosquito coil' with 'I am more likely to get dengue than the people around me' (r=.136, p<0.05).

Preventive Measures against Self-Efficacy

When the various preventive measures were put together with statements that assessed 'self-efficacy', almost all the statistically significant correlations were positive (Table 11). The strongest correlation recorded was between '5-Step Mozzie Wipeout' and 'I regularly carry out the 5-Step Mozzie Wipeout to ensure that there are no mosquitoes breeding in my home' (r=.485, p<0.01), followed closely behind between '5-Step Mozzie Wipeout' with 'I have enough information to know how to do the 5-Step Mozzie Wipeout' (r=.431, p<0.01). I also observed that '5-Step Mozzie Wipeout' also recorded statistically significant correlations for all statements under 'Self-Efficacy'. The weakest correlation recorded was between 'Covering water storage' with 'I have enough information about how to protect myself and my family from dengue/Zika' (r=.118, p<0.05) and 'Eliminating standing water containers' with 'I have enough information about how to protect myself and my family from dengue/Zika' (r=.121, p<0.05).

Table 10. Pearson correlations between the various preventive measures and the statements under the category of "Perceived Susceptibility".

	I am exposed to Aedes mosquitoes	I am vulnerable to mosquito-borne diseases	I am more likely to get Dengue than the people around me	My immune system protects me from getting Dengue/Zika	My past experiences make me believe that I am not likely to get Dengue/Zika even if my friends get it
	(5 = Strongly Agree)	(5 = Strongly Agree)	(5 = Strongly Agree)	(5 = Strongly Disagree)	(5 = Strongly Disagree)
Eliminating standing water containers	.020	052	030	068	149*
Use air-conditioning or fan	005	.000	.095	058	056
Covering water storage	017	.047	.054	108	156**
5-Step Mozzie Wipeout	044	045	.038	046	066
Using insect repellent on skin	.057	.154**	.197**	006	062
Wear protective, long-sleeved clothing	056	.034	.013	.045	.038
Limiting outdoor activity during peak mosquito biting times	.023	012	.038	.041	005
Burn Mosquito Coil	.022	.086	.136*	.016	.031
Use an electronic bug/insect zapper	024	.090	.114	061	.091
Installing insect screens on windows/doors	134*	024	016	.029	.053
Sleeping under mosquito bed net	045	.081	.207**	056	.012

^{**} p < 0.01, * p < 0.05

Table 11. Pearson correlations between the various preventive measures and the statements under the category of "Perceived Self-Efficacy".

	I am confident that I can prevent myself from getting Dengue/Zika	I have enough information about how to protect myself and my family from Dengue/Zika	I have enough information to know how to do the 5-Step Mozzie Wipeout	I regularly carry out the 5-Step Mozzie Wipeout to ensure that there are no mosquitoes breeding in my home
Eliminating standing water containers	.057	.121*	-	-
Use air-conditioning or fan	.014	.060	-	-
Covering water storage	.070	.118*	-	-
5 Step Mozzie Wipeout	.180**	.144*	.431**	.485**
Using insect repellent on skin	132*	070	-	-
Wear protective, long-sleeved clothing	019	059	-	-
Limiting outdoor activity during peak mosquito biting times	.013	.000	-	-
Burn Mosquito Coil	.032	050	-	-
Use an electronic bug/insect zapper	067	068	-	-
Installing insect screens on windows/doors	.046	026	-	-
Sleeping under mosquito bed net	089	129*	-	-

^{**} p < 0.01, * p < 0.05

Preventive Measures against Response Efficacy

Lastly, the individual preventive measures were put alongside the statements of 'Perceived Response Efficacy' in the bivariate analysis. From the results, there were only a few statistically significant correlations (Table 12). The strongest correlation was that of '5-Step Mozzie Wipeout' with 'The 5-Step Mozzie Wipeout is effective to prevent mosquitoes from breeding in my house' (r= .289, p<0.01) as well as with 'I am able to protect myself and my family from getting dengue/Zika just by doing the 5-Step Mozzie Wipeout' (r= .281, p<0.01). The weakest significant correlation was negative, between 'Sleeping under mosquito bed net' and 'Using other recommended dengue/Zika preventive measures will decrease my chances of getting infected with dengue/Zika' (r= -.149, p<0.05).

Table 12. Pearson correlations between the various preventive measures and the statements under the category of "Perceived Response Efficacy".

	I am able to protect myself and my family from getting Dengue/Zika just by doing the 5- step Mozzie Wipeout	Using other recommended Dengue/Zika preventive measures will decrease my chances of getting infected with Dengue/Zika	The 5-Step Mozzie Wipeout is effective to prevent mosquitoes from breeding in my house
Eliminating standing water containers	.024	005	-
Use air-conditioning or fan	.023	010	-
Covering water storage	.097	041	-
5-Step Mozzie Wipeout	.281**	-	.289**
Using insect repellent on skin	020	040	-
Wear protective, long-sleeved clothing	.110	019	-
Limiting outdoor activity during peak mosquito biting times	.085	.044	-
Burn Mosquito Coil	.044	046	-
Use an electronic bug/insect zapper	051	023	-
Installing insect screens on windows/doors	.056	085	-
Sleeping under mosquito bed net	085	149*	-

^{**} p < 0.01, * p < 0.05

Linear Regression with Preventive Measures and the various EPPM categories

Finally, the top five preventive measures that were reported to be frequently used, were put to a stepwise regression test to see which of the variables have the highest influence that influenced preventive behaviour towards the individual. However, only the '5 Step Mozzie Wipeout (MW)' recorded significant results and have been included in this report.

In the stepwise regression method (with MW as the dependent variable), SPSS starts with zero predictors and then adds the strongest predictor ('Self-efficacy (SE)') to the model as its b-coefficient is statistically significant (p < 0.01). It will then add the next strongest predictor (in this case, 'Severity (S)') and so on. The process stops here as none of the other predictors contributes significantly to the included predictors. Thus, in the full model (i.e. Model 2 in Table 13) generated by SPSS, explaining 19.7% of the variance in carrying out the '5-Step Mozzie Wipeout', 'Self-efficacy' showed the highest b-coefficient (B = .534, p < 0.01), followed by 'Severity' (B = .214, p < 0.05) (Table 13). The final model states that:

$$MW = -0.735 + (0.534 \cdot SE) + (0.214 \cdot S)$$
 Equation 1.

From Equation 1, it can be seen that the strongest predictor is 'Self-efficacy', where a 1-point increase is associated with a 0.534-point increase in carrying out the '5-Step Mozzie Wipeout', followed by 'Severity', where a 1-point increase is associated with a 0.214-point increase. However, it is good to note that the model does not prove that this relation is causal but it seems reasonable that improving self-efficacy and if people's perception of severity of mosquito-borne diseases increases, it might lead to an increase in carrying out the '5-Step Mozzie Wipeout'.

Table 13. Regression analysis to test associations between EPPM determinants & Experience with 5-Step Mozzie Wipeout as the dependent variable (DV)

DV: 5-Step Mozzie Wipe-out	В	t	R ²	R ² change
Model 1:	·	<u>.</u>	.185	.185
Self-Efficacy	.528	8.290**	.103	.103
Model 2:	.520	0.230	.197	.012
Self-Efficacy	.534	8.430**		
Severity	.214	2.162*		

^{**}p<0.01, *p<0.05

5 Evaluation of the Dutch mosquito citizen science network

Before starting or intensifying a citizen-science approach, it is useful to study existing citizen science projects. This will provide a better understanding and insight into how citizen science projects are organized, as well as the usefulness of the data collected. For this particular chapter, the results following the analysis of the Muggenradar data, together with the calculated mosquito nuisance prediction based on Oosterbroek's (2011) prediction model will be analysed in greater detail to address the third research question of how citizens can contribute towards data collection in a citizen science project.

Firstly, I looked into the number of nuisance reports that were submitted on Muggenradar. Based on the submitted nuisance reports, a graph was generated to show the total number of nuisance reports submitted on a weekly basis (Figure 14). However, only the period between week 23 and week 38 were included to prevent too much details in a graph. The counts of nuisance for 2016 only started in week 27 as it was launched on 29th June 2016 (week 26) and it also registered one of the highest count of nuisance reports for 2016. On the graph, it can also be observed that there are several peaks in the various weeks and this is largely due to media attention and appearances.

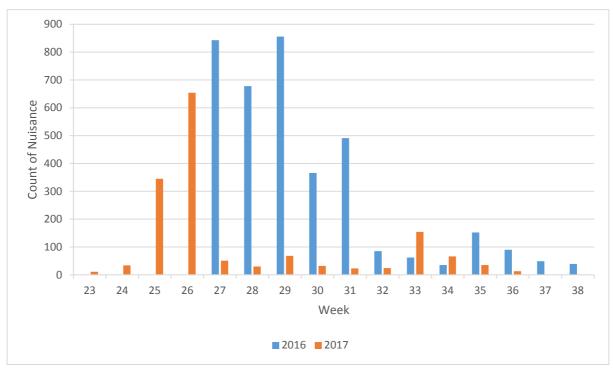


Figure 14. Weekly count of Nuisance reports submitted to Muggenradar between the 23rd and 38th week in 2016 and 2017. Nuisance reports only started from week 27 in 2016 as Muggenradar was launched on 29th June 2016 (Week 26).

Next, I went deeper and looked into the types of nuisance reported by the public as well as to see the affect media attention would have on the types of reports. A stacked graph was created to show the distribution of the types of nuisance submitted over the total count of nuisance for a particular week. I was informed by experts of the Muggenradar team that a newsletter from Nature Today²⁴ was sent out (Week 33 of 2017, 14-20 August) to remind their readers to submit mosquito nuisance reports,

²⁴ Nature Today is a website to inform readers on developments in nature, in order to get people more connected with nature and increase their knowledge on nature. This helps to cultivate their appreciation for nature, in hopes that readers will be more motivated to contribute to monitoring, management and preservation of nature. Nature Today. (n.d.). Retrieved March 13, 2018, from https://www.naturetoday.com/intl/en/aboutnaturetoday/about-nature-today

regardless of whether they experienced mosquito nuisance or not. As such, I sieved out the data for the weeks before and after week 33 in 2017 to see if there were any observable differences in the reports submitted. The distribution of the types of reports submitted are in Figure 15. From the stacked graphs, it can be observed that there was a significant increase in the numbers of "no nuisance" reported by the public – from only two "no nuisance" reports in week 32, to 101 "no nuisance" reports in week 33. However, the subsequent weeks after week 33, the "no nuisance" reports started to decline again.

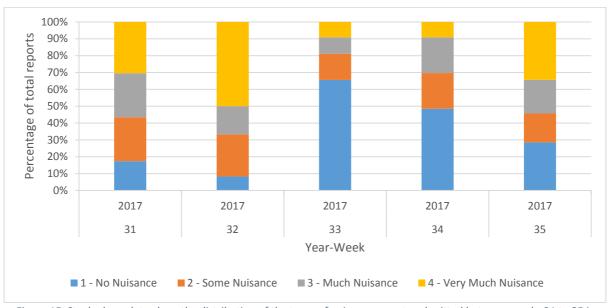


Figure 15. Stacked graph to show the distribution of the types of nuisance reports submitted between weeks 31 to 35 in 2017. The Muggenradar team sent a newsletter out to their subscribers in week 33 to call for mosquito nuisance reports, including submission of "no nuisance" reports if their followers did not experience any nuisance.

Next, to see if there would be any temporal patterns in variations between reported nuisance and predicted nuisance, I put both sets of data into a graph. Figure 16 shows the monthly average nuisance score from Muggenradar reports alongside the monthly average predicted nuisance calculated based on the Muggenradar team's expert judgement and Oosterbroek's (2011) model. Figure 17 is based on the same data, but depicts the weekly average instead. From both Figure 16 and Figure 17, a seasonality pattern can be observed in the predicted nuisance score. This is so as the predicted nuisance score is completely based on weather parameters. The predicted nuisance score increases in springtime (March to May/June), peaks in summer (June/July to September), begins to decrease in autumn (September/October to November/December) and remains low in winter (December to February/March). However, I was unable to detect any clear patterns in the nuisance score based on submitted reports alone. When comparing the reported and predicted nuisance together, there is also not a distinct pattern that can be concluded but I did observe some similarities in the way that both the reported and predicted scores decreased and peaked in some periods (e.g. between October 2016 to January 2017 in Figure 16).

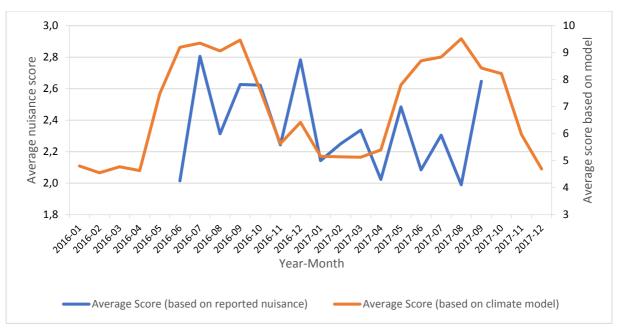


Figure 16. Combination of (monthly) average nuisance score from Muggenradar reports and average score calculated based on model developed by Oosterbroek (2011)

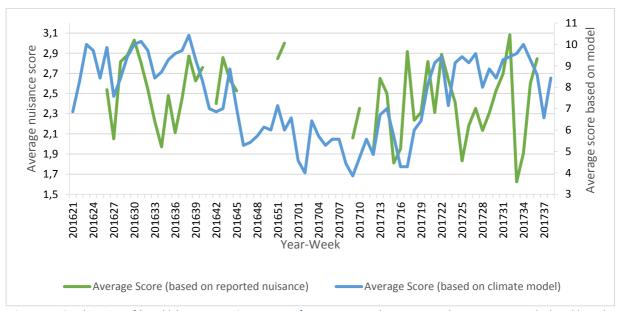


Figure 17. Combination of (weekly) average nuisance score from Muggenradar reports and average score calculated based on model developed by Oosterbroek (2011)

As there was no distinct pattern to be observed, a scatterplot was carried out to determine if there was any relationship between the average reported nuisance scores and the average predicted nuisance scores. Figure 18 shows the correlation between the monthly average nuisance scores and the modelled nuisance score while Figure 19 presents the correlation between the weekly average nuisance score and modelled nuisance. The R^2 values of 0.0257 (monthly) and 0.0342 (weekly) indicate that there is no relationship between the two variables.

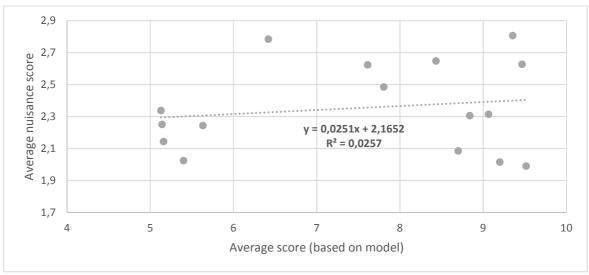


Figure 18. Scatterplot based on monthly average nuisance score and predicted mosquito nuisance score based on Oosterbroek's (2011) model parameters

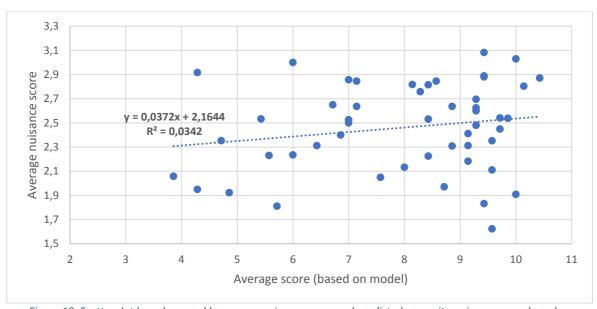


Figure 19. Scatterplot based on weekly average nuisance score and predicted mosquito nuisance score based on Oosterbroek's (2011) model parameters.

6 Stakeholders' Perception of a Citizen-Science Approach

6.1 Introduction to interviews with stakeholders

In this chapter, the stakeholders' perception of a citizen-science approach will be discussed and assessed, to see if there is any potential to start a new or intensify current citizen science initiatives surrounding mosquito monitoring in Singapore. The information collated for this section is mostly derived from the interviews that were carried out in Singapore between July 2017 to August 2017. In total, I interviewed seven experts/stakeholders that were from different organizations but are actively engaged in the mosquito scene in Singapore. The list of interviewees and their organizations and institutions are listed in Table 14.

#	Interviewee (Date)	Affiliations
1	Dr Julien Pompon (26 July 2017)	 Assistant Professor, Emerging Infectious Diseases Programme, Duke-NUS Medical School
2	Dr Alex Cook (26 July 2017)	 (Primary) Vice Dean (Research) and Domain Leader (Biostatistics & Modelling), Saw Swee Hock School of Public Health (Joint) Associate Professor at the Yale-NUS College, the Department of Statistics and Applied Probability, NUS Yong Loo Lin School of Medince, and the Program in Health Services and Systems Research at the Duke-NUS Graduate Medical School Singapore
3	Dr Hsu Li Yang (3 August 2017)	 Programme Leader (Antimicrobial Resistance), Saw Swee Hock School of Public Health Adjunct Associate Professor at NUS Yong Loo Lin School of Medicine Senior Consultant and Head, Department of Infectious Diseases, Tan Tock Seng Hospital Deputy Clinical Director, Communicable Diseases Centre, Ministry of Health
4	Dr Roman Carrasco (10 August 2017)	 Assistant Professor, Department of Biological Sciences, National University of Singapore (NUS)
5	Dr Ian Mendenhall (22 August 2017)	 Principal Research Scientist, Emerging Infectious Diseases Research Program, Duke-NUS Medical School
6	Prof May Oo Lwin (22 August 2017)	 Associate Dean (Special Projects), College of Humanities, Arts, & Social Sciences Director, University Scholars Programme Wee Kim Wee School of Communication and Information College of Humanities, Arts, & Social Sciences
7	Dr Christina Liew (23 August 2017)	 Assistant Director (Partnerships), Environmental Health Institute (EHI), National Environment Agency (NEA)

Table 14. List of interviewees and the organizations/institutions they represent.

I introduced citizen science to the various experts by explaining the example of Muggenradar in the Netherlands (see Section 1.2.1). It was during the interview with Dr Alex Cook that I found out about the myENV app by NEA and about MoBuzz (which will be elaborated later in Section 6.3), which was started by Prof May Oo Lwin and her team.

From the interviews, I identified four main themes surrounding the topic on implementing and intensifying a citizen-science approach in Singapore. The themes are:

- (1) Perception of current surveillance and control efforts;
- (2) Applicability of citizen science initiatives in the Singapore context;
- (3) Potential challenges of a citizen-science approach; and
- (4) Stakeholders' willingness to participate in a citizen-science approach.

I used these themes to guide the analysis of the interview results to answer RQ3 which was to find out stakeholders' perception towards a citizen-science approach.

6.2 Perception on current surveillance and control efforts

Firstly, before I introduced the concept of citizen science to the various stakeholders, I asked them about their thoughts with regards to current mosquito surveillance and control efforts in Singapore. All the stakeholders cited the extensive and tremendous efforts that the National Environment Agency (NEA) of Singapore has carried out and most of them agree that a lot is being done to target the mosquito problem. They praised the efforts and willingness of NEA/EHI to continuously try new techniques (e.g. Wolbachia) to target the mosquito problem (Dr Ian Mendenhall, Prof May). However, there are some who also thought more could be done, citing that there was a period of intensified mosquito control which led to a fall in dengue cases, thus there is room for more to be done (Dr Hsu Li Yang).

In addition, a few of the stakeholders also voiced their concern about it being a top-down approach and whether it may result in the locals taking it for granted. As the measures are mostly introduced by governmental agencies, the various experts worried about whether there is too much reliance on the government to handle such things that the local community does not take the necessary precautions to protect themselves against mosquito breeding (Dr Alex Cook, Dr Christina Liew).

6.3 Applicability of citizen science initiatives in the Singapore context

I went on to introduce them to the concept of citizen science and shared with them about Muggenradar in the Netherlands as an example of mosquito-related citizen science projects. I described to them how the public were taught to catch and send in mosquitoes as well as submit mosquito nuisance reports. When asked on the applicability of such an approach in the Singapore context, I received mixed responses from the various experts. Some of them thought that it was an interesting initiative and were for the idea, but there were some that did not see how such a citizenscience approach can add value to existing surveillance and control.

Those that like the idea suggested some interesting ideas for consideration. Some of these ideas included having a real time reporting inclusive of location coordinates being recorded. For example, Dr Roman Carrasco suggested for an app that would have a real time reporting of mosquito bites — when people get bitten, they can report and subsequently update if they got dengue; Dr Julien Pompon suggested that this initiative could be used to help NEA/EHI with monitoring the spread of Wolbachia mosquitoes in Project Wolbachia (see Section 3.3.1); and Dr Ian Mendenhall suggested to get the community to host traps in their homes so as to help with catching mosquitoes for research e.g. hosting Gravitraps or ovi-postion cups to trap mosquitoes.

It was during the interview with Dr Alex Cook that I came to know about some examples of mobile phone applications that contains elements of a citizen-science approach. The examples Dr Cook shared were the *myENV* app by NEA (see Section 3.3.5) and MoBuzz by Prof May Lwin and her team in Nanyang Technological University (NTU) and Centre of Social Media Innovations for Communities (COSMIC). With the example of myENV, Dr Alex Cook shared that users could input addresses that were important to them (e.g. home address, workplace etc), so that they could receive push notifications from the app should there be a dengue cluster around that area. Furthermore, Dr Alex Cook added that since so much is already in place to target this mosquito problem as well as the amount of data that NEA and the Ministry of Health (MOH) has (number of dengue cases, information about mosquito breeding, weather data, etc.), he does not see how such an approach getting people to send in mosquitoes or reporting nuisance will help, especially in the prediction modelling for dengue.

Following that interview, I managed to reach out to Prof May Lwin to arrange for an interview and found out more about *MoBuzz*. According to Prof May Lwin, *MoBuzz* is an integrated mobile and desktop based health risk communication and response approach to tackling dengue in Asia. It is

designed as a participatory form of disease surveillance, and many considered it to be a form of citizen science MoBuzz has three main components that includes predictive surveillance, civic engagement as well as health communication. MoBuzz has since been introduced in Colombo, Sri Lanka in (which year) and is currently in its first phase of deployment testing. The first phase of deployment consists mainly of Public Health Inspectors (PHIs) using MoBuzz as an alternative form of data collection and recording as opposed to manually recording and keying data after house visits to check for mosquito breeding spots. The next phase of deployment would be to introduce MoBuzz as a mobile phone application for the general public in Colombo to report breeding sites, symptoms of dengue and mosquito bites, as well as for health authorities to use MoBuzz as a form of health communication to inform the public about dengue hotspots and recommend preventive measures (Lwin et al., 2014; Smolinski, Crawley, Olsen, Jayaraman, & Libel, 2017). However, when asked on MoBuzz's applicability in Singapore, Prof May mentioned that it was not introduced in Singapore because the health authorities were more concerned about a next SARS-like pandemic, as it had significant impacts on Singapore and her economy in 2003. It was also mentioned in other interviews with Dr Alex Cook and Dr Ian Mendenhall, that the diseases burden of dengue in Singapore is not as high as other South-East Asian (SEA) countries.

6.4 Potential challenges of a citizen-science approach

Besides the applicability of a citizen-science approach, the various stakeholders also pointed out some challenges when implementing such an approach in the Singapore context. Dr Ian Mendenhall, who is an entomologist by training and studies mosquitoes, mentioned that "Aedes mosquitoes are difficult to catch, are usually skittish around the ankles and tends not to present themselves in a way that makes it easy to be caught". Furthermore, Dr Alex Cook also mentioned that mosquitoes are difficult to identify unless one is a specialist in the field of mosquitoes.

When I spoke to Dr Christina Liew (EHI) as well as Prof May on the possibilities of rolling out something similar like MoBuzz in Singapore, which has location coordinates involved when the Health Inspectors use the app, both of them mentioned the difficulties of pin-pointing an exact location as Singapore is small, dense and there are many high-rise residential areas.

With reference to the MoBuzz app, Prof May Lwin also highlighted that her team noticed that people were reluctant at first when the app was introduced to them. There was a high inertia to learn as well as accept this new way of reporting and data collection. Besides the initial reluctance, Prof May also stated that there is a challenge to ensure sustainability of such an initiative once people are on board, as well as a challenge to instil and ensure vigilance in the community even when there is no apparent threat.

6.5 Stakeholders' willingness to participate in a citizen-science approach

All in all, almost all the various stakeholders that I interviewed were interested in this approach and willing to participate in such an initiative. Those that work directly with mosquitoes were interested to get their hands on mosquito samples for research purposes. However, for Dr Julien Pompon, he highlighted that should mosquitoes be sent in as part of a citizen-science approach, it would require people to submit the mosquitoes in Eppendorf tubes with 70% ethanol inside to preserve the DNA. But Dr Ian Mendenhall, who also works with mosquitoes, maintains that the former might not be necessary, but it would be dependent on what kind of information the researcher or organization behind it would like to retrieve. In addition, Prof May Lwin commented that while it is possible to incorporate algorithms and layers on to an app like MoBuzz to include mosquito breeding and nuisance reporting, it would also be good to first study the usefulness and effectiveness of such an approach, to see how such data from the public can value add towards science and society in general.

7 Influencing Participation in Citizen Science Projects

Having assessed the preventive behaviour in Singapore as well as the value of a citizen-science approach, the next step before starting a citizen science project is to look into the factors that will influence participation. This chapter, I will investigate the Singapore public's willingness to participate in a citizen science project, as well what might influence their participation and will address the fifth research question to find out the factors that influence active participation in citizen science projects. The results of the online public perception survey (Appendix B) will be used for this chapter.

7.1 Ground sensing of "citizen science" in Singapore

Citizen science is a relatively new concept in Singapore. Based on the responses to the survey questions, only 23 (7.2%) respondents reported that they participate in citizen science projects and some of the examples listed were: Flumob, Galaxyzoo, NPARKS' birds, butterflies and dragonflies observations (Appendix B). When asked if respondents knew of any existing mobile phone applications of websites that allows them to report mosquito nuisance or breeding, only 37 (11.6%) of respondents said they were aware, and most of them mentioned the apps mentioned in Section 3.3.5 (myENV and OneService). This shows that the take-up rates of such apps available are not quite high yet and that very little people actually know of these apps' existence.

7.2 Willingness to participate in citizen science projects

When polled on their willingness to participate in a citizen science project to help with mosquito surveillance and control, 42 (13.2%) responded with a 'Yes' and 176 (55.2%) said 'Maybe' and the rest responded 'No'. As such, I was curious to find out what might be some potential factors that might influence respondents' willingness to participate. To do this, I used the rest of my survey to see if it can provide some insights into various factors that might explain people's willingness to participate in a citizen science project.

7.3 Factors influencing participation in mosquito-related citizen science projects

I did a series of chi-square tests for independence, to see if there are any associations between various categorical variables; a significance level was set at p < 0.05. In this study, it was assumed that the respondents that indicated 'Maybe' in their interest to participate in a citizen science project are more inclined to be interested once they have more information and have thus been combined into one group with respondents that chose 'Yes' to participate in mosquito-related. Thus the chi-square tests were to test various questions with categorical variables against 'Yes' or 'No' responses to willingness to participate in a citizen science initiative.

Susceptibility score against willingness to participate

I first looked into respondents' perception of their susceptibility and their willingness to participate in a citizen science project. To do this, I used the average scores from the 'Perceived susceptibility' type of statements. As the susceptibility scores were over a range between 1 and 5, I divided the respondents into two groups. Those with scores less than 2.5 will be considered 'not susceptible' and scores higher than 2.5 will be considered 'susceptible'. However, the chi-square test revealed that there was no significant association between respondents' 'Perceived susceptibility' score and their willingness to participate (Table 15). Since there was no significant correlation between the susceptibility score and willingness to participate, I went on to test the individual statements under the 'susceptibility' category.

Vulnerability to mosquito-borne diseases against willingness to participate

Having tested the various statements under 'Perceived susceptibility' individually, only 'I am vulnerable to mosquito-borne diseases' recorded a significant correlation. To find out if respondents' feeling of vulnerability with regards to mosquito-borne diseases would influence people's motivation

to participate in a citizen science project, I tested the responses of 'I am vulnerable to mosquito-borne diseases' with respondents' willingness to participate. There were five different options given, ranging from 'Strongly agree' to 'Strongly disagree' as well as 'I don't know'. The responses were regrouped into two separate groups - (1) respondents feeling vulnerable to MBD (265 respondents, 85.8%) and (2) respondents that do not feel vulnerable to mosquito borne diseases (44 respondents, 14.2%). The chi-square test revealed that there is a significant association between respondents' willingness to participate if they feel vulnerable to mosquito-borne diseases (p < 0.05) (Table 15).

Biting experienced in the past week against willingness to participate

To find out if getting bitten would influence people's motivation to participate in a citizen science project, I tested the responses of 'How often were you bitten by mosquitoes in the past week' with respondents' willingness to participate. There were five different options given, ranging from 'Daily' to 'I got bitten 1/2-3/4-6 days of this week' to 'I did not get bitten'. In order to carry out the chi-square test, I re-grouped the options into 'I experienced biting nuisance this week' and 'I did not experience biting nuisance this week'. After the regrouping, there were 179 (56.1%) respondents that experienced mosquito biting nuisance that week and 140 (43.9%) that did not experience any mosquito biting nuisance. The chi-square test revealed that there is a significant association between respondents' willingness to participate if they experienced mosquito biting nuisance (χ^2 (1) = 6.703, p < 0.05) (Table 15).

Mosquito nuisance experienced against willingness to participate

Besides finding out if there was an association between being bitten by mosquitoes and people's willingness to participate, I also tested for an association between people's willingness to participate with people's experience with mosquito nuisance. As this question allowed for multiple options to be picked, I tested the responses of the option 'I did not experience any mosquito nuisance', grouping the responses into 'No, I did not experience mosquito nuisance' for those that picked the option (187 respondents, 58.6%), and the rest were grouped into 'Yes, I experienced mosquito nuisance' because they did not select the option. From the chi-square tests, there was a significant association between experiencing mosquito nuisance and people's willingness to participate (p = 0.024). However, as the chi-square tests only shows if there is an association between two categorical variables, it does not show what exactly the relationship is. Upon closer inspection of the cross-tabulations that were generated together with the results of the chi-square, I noticed that amongst the four different types of outcomes, the outcome where people did not experience mosquito nuisance and stated that they were willing to participate in citizen science project recorded the most number of respondents (137 respondents, 42.9%) (Table 15).

Responsibility to keep mosquitoes away against Willingness to participate

Next I wanted to test if there was an association between who people thought was responsible to keep mosquitoes away (Q21 in survey) and their willingness to participate. Thus I did a chi-square test on the various options with respondents' willingness to participate. As this question allowed for multiple options to be picked, I tested each option separately with the willingness to participate, with responses for each option segregated to 'Yes' if respondents picked that option and 'No' if that option was not picked. From the results of the chi-square tests, the options that had significant correlations with the willingness to participate were 'Personal Responsibility' (p = 0.002), 'Town Council' (p = 0.007), 'Families' (p = 0.038) and 'Government' (p = 0.044) (Table 16).

Table 15. Cross-tabulations of various questions in the survey that recorded a significant response in the chi-square test

			Are you willing in a CS p			Asymptotic Significance
			Yes/Maybe	No	Total	(2-sided)
I am susceptible	Yes	Count	182	81	263	
(based on		% of Total	57.1%	25.4%	82.4%	
Susceptibility score)	No	Count	36	20	56	
		% of Total	11.3%	6.3%	17.6%	.473
Total	-	Count	218	101	319	
		% of Total	68.3%	31.7%	100.0%	
			Are you willing			Asymptotic
			in a CS p			Significance
			Yes/Maybe	No	Total	(2-sided)
I am vulnerable to	Yes	Count	188	77	265	
MBD		% of Total	60.8%	24.9%	85.8%	
	No	Count	24	20	44	.030*
	_	% of Total	7.8%	6.5%	14.2%	
Total		Count	212	97	309	
		% of Total	68.6%	31.4%	100.0%	
			Are you willing in a CS p			Asymptotic Significance
			Yes/Maybe	No	Total	(2-sided)
Were you bitten by	Yes	Count	133	46	179	
mosquitoes in the		% of Total	41.7%	14.4%	56.1%	
past week?	No	Count	85	55	140	
		% of Total	26.6%	17.2%	43.9%	.010*
Total	-	Count	218	101	319	
		% of Total	68.3%	31.7%	100.0%	
			Are you willing in a CS p			Asymptotic
			Yes/Maybe	No	Total	Significance (2-sided)
Did you experience	Yes	Count	81	51	132	(2 slaca)
mosquito nuisance?	163	% of Total	25.4%	16.0%	41.4%	
ooquitouiouiioci		/0 UI TULAI				
	No	Count	127	5∩ l	197	
	No	Count % of Total	137 42 9%	50 15.7%	187 58.6%	.024*
Total	No	Count % of Total Count	137 42.9% 218	50 15.7% 101	58.6% 319	.024*

Table 16. Cross-tabulations of various questions in the survey that recorded a significant response in the chi-square test

Who do you think is responsible for keeping mosquitoes away?		Are you willing to participate in a CS project?			Asymptotic Significance	
		Yes/Maybe	No	Total	(2-sided)	
	Yes	Count	134	50	184	
Government		% of Total	42.0%	15.7%	57.7%	
Government	No	Count	84	51	135	.044
		% of Total	26.3%	16.0%	42.3%	
Total		Count	218	101	319	
		% of Total	68.3%	31.7%	100.0%	
Who do you think is re	sponsi	ble for		ng to participate		Asymptotic
keeping mosquitoes a			Yes/Maybe	S project? No	Total	Significance (2-sided)
	Yes	Count	166	62	228	(Z diada)
	100	% of Total	52.0%	19.4%	71.5%	
Town Council	No	Count	52	39	91	
		% of Total	16.3%	12.2%	28.5%	.007
Total		Count	218	101	319	
		% of Total	68.3%	31.7%	100.0%	
Who do you think is re	enonei	ble for		ng to participate		Asymptotic
keeping mosquitoes a		bie ioi		S project?		Significance
3 11 11 11 11	,		Yes/Maybe	No	Total	
	` '					(2-sided)
	Yes	Count	155	60	215	(2-sided)
Family Members		% of Total	155 48.6%	18.8%	215 67.4%	(2-Sided)
Family Members	Yes No	% of Total Count	155 48.6% 63	18.8% 41	215 67.4% 104	.038
		% of Total Count % of Total	155 48.6% 63 19.7%	18.8% 41 12.9%	215 67.4% 104 32.6%	
Family Members Total		% of Total Count % of Total Count	155 48.6% 63 19.7% 218	18.8% 41 12.9% 101	215 67.4% 104 32.6% 319	
		% of Total Count % of Total	155 48.6% 63 19.7% 218 68.3%	18.8% 41 12.9% 101 31.7%	215 67.4% 104 32.6%	.038
Total	No	% of Total Count % of Total Count % of Total	155 48.6% 63 19.7% 218 68.3% Are you willin	18.8% 41 12.9% 101 31.7% ag to participate	215 67.4% 104 32.6% 319	.038
	No	% of Total Count % of Total Count % of Total	155 48.6% 63 19.7% 218 68.3% Are you willin	18.8% 41 12.9% 101 31.7%	215 67.4% 104 32.6% 319	.038
Total Who do you think is re	No	% of Total Count % of Total Count % of Total	155 48.6% 63 19.7% 218 68.3% Are you willin in a CS	18.8% 41 12.9% 101 31.7% og to participate 5 project?	215 67.4% 104 32.6% 319 100.0%	.038 Asymptotic Significance
Total Who do you think is re	No	% of Total Count % of Total Count % of Total ble for keeping	155 48.6% 63 19.7% 218 68.3% Are you willin in a CS Yes/Maybe	18.8% 41 12.9% 101 31.7% ag to participate Sproject? No	215 67.4% 104 32.6% 319 100.0%	.038 Asymptotic Significance
Total Who do you think is re mosquitoes away?	No	% of Total Count % of Total Count % of Total ble for keeping Count	155 48.6% 63 19.7% 218 68.3% Are you willin in a CS Yes/Maybe	18.8% 41 12.9% 101 31.7% og to participate 5 project? No 89	215 67.4% 104 32.6% 319 100.0% Total	.038 Asymptotic Significance (2-sided)
Total Who do you think is remosquitoes away? Personal	No No Pesponsi	% of Total Count % of Total Count % of Total ble for keeping Count % of Total	155 48.6% 63 19.7% 218 68.3% Are you willin in a CS Yes/Maybe 211 66.1%	18.8% 41 12.9% 101 31.7% og to participate project? No 89 27.9%	215 67.4% 104 32.6% 319 100.0% Total 300 94.0%	.038 Asymptotic Significance
Total Who do you think is remosquitoes away? Personal	No No Pesponsi	% of Total Count % of Total Count % of Total ble for keeping Count % of Total Count	155 48.6% 63 19.7% 218 68.3% Are you willin in a CS Yes/Maybe 211 66.1%	18.8% 41 12.9% 101 31.7% og to participate 8 project? No 89 27.9%	215 67.4% 104 32.6% 319 100.0% Total 300 94.0%	.038 Asymptotic Significance (2-sided)

Motivation to participate

Lastly, I looked into the simple descriptive statistics into what motivations people might have for participating in a citizen science project. Respondents were given various options to pick from and the results from this question are shown in Figure 20. The top three motivations as picked by the respondents are 'to learn how to better protect myself and my loved ones from mosquitoes and MBD' (210 respondents, 65.8%), 'to contribute towards mosquito surveillance and monitoring' (194, 60.8%) and 'fun activities and events that surround the project' (112, 35.1%). For those that picked 'Others' indicated motivations such as if it does not take up too much time, that the project will be taken and done seriously and participants are informed of the progress and outcomes, and some included monetary incentives as motivation (refer to Appendix B).

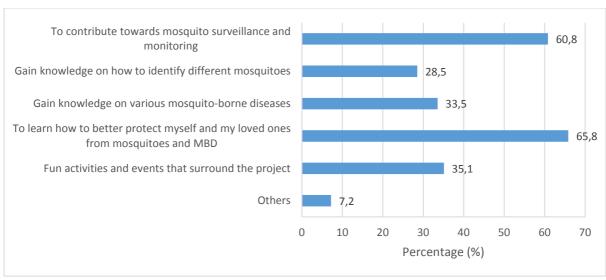


Figure 20. Bar chart showing what motivates respondents to participate in a mosquito-related citizen science project

Following the analysis of the descriptive statistics of what motivates respondents to participate, I also carried out chi-square test to find out if any of the given 'motivation' options are associated with the willingness to participate in a mosquito-related citizen science project. Likewise, as this question allowed for multiple options to be picked, I tested each option separately with the willingness to participate, with responses for each option segregated to 'Yes' if respondents picked that option and 'No' if that option was not picked. From the results of the chi-square tests, the option that had a significant association was that of 'To learn how to better protect myself and my loved ones from mosquitoes and mosquito-borne diseases' (p < 0.01).

7.4 Preferred communication channels and types of information

After finding out what some potential factors could be influencing people's participation in a mosquito-related citizen science, the next thing I analysed was their preferred channels of receiving information and the type of information that they would like to receive. Information gathered for this section are from the survey and it consists of simple descriptive statistics (Appendix B).

In the survey, one of the questions was to find out which communication channels respondents' preferred to receive news and information from. The options included mobile phone applications, online newsletters, print media (magazines and newspapers), radio, social media, television, word-of-mouth. Respondents were allowed to pick multiple answers for this question. From the results of the survey (Figure 21), we can see that the top three preferred choices of receiving information are social media (193 respondents, 60.5%), television (148, 46.4%) and mobile phone applications (132, 41.4%).

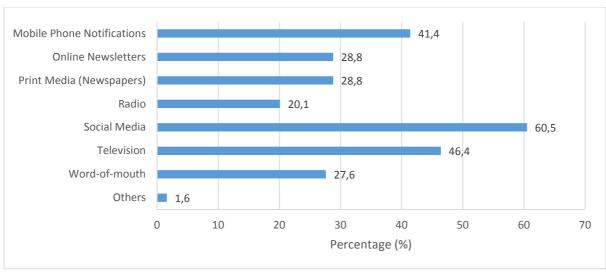


Figure 21. Bar chart showing respondents' preferred channels/medium to receive news and information from.

Following the analysis of the descriptive statistics of the preferred channels of communication, I also carried out chi-square test to see if there were any preferred communication channels associated with the willingness to participate in a mosquito-related citizen science project. From the results of the chi-square tests, only the option of 'Mobile Phone Notifications' recorded a significant association (p < 0.05) (Table 17). However, as the chi-square tests only shows if there is an association between two categorical variables, it does not show what exactly the relationship is. Upon closer inspection of the cross-tabulation (Table 17), I noticed that while the largest group of respondents (115 respondents, 36.1%) picked mobile phone applications as a preferred form of communication channel and were also willing to participate in a citizen science project, the next biggest group of respondents (103 respondents, 32.3%) were willing to participate in the project but did not pick mobile phone notifications as their preferred channels of communication.

Table 17. Chi-square test and cross-tabulations of respondents' preferred medium of communication and their willingness to participate in a citizen science project

I prefer to receive information through the following channels:			Are you willing in a CS Yes/Maybe	g to participate project? No	Total	Asymptotic Significance (2-sided)
Mobile Phone	Yes	Count	115	72	187	(
Notifications		% of Total	36.1%	22.6%	58.6%	
(apps/websites/	No	Count	103	29	132	.002
SMS)		% of Total	32.3%	9.1%	41.4%	
Total		Count	218	101	319	
		% of Total	68.3%	31.7%	100.0%	

Next after knowing the preferred channels of communication, I also looked into the descriptive statistics of the kind of information that people would like to receive with regards to mosquitoes and mosquito-borne diseases. The results for this are shown in Figure 22. From the respondents' responses, the top three types of information that respondents would like to receive are 'Alerts when there are outbreaks of MBD in (my) area' (232 respondents, 72.7%), 'Alerts for mosquito "season" (202, 63.3%) and 'How to protect yourself and your loved ones from mosquitoes' (174, 54.5%).

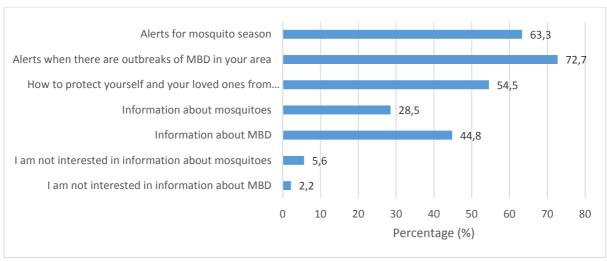


Figure 22. Bar chart showing the types of information that respondents' indicated that they would like to receive

Following the analysis of the descriptive statistics on the types of information that respondents would like to receive, I also carried out chi-square tests to find out if any of the 'information' options are associated with the willingness to participate in a mosquito-related citizen science project. I tested each option separately with the willingness to participate, with responses for each option segregated to 'Yes' if respondents picked that option and 'No' if that option was not picked. From the results of the chi-square tests, the options of 'How to protect yourself and your loved ones from mosquitoes' (p<0.01), 'When there are outbreaks of mosquito-borne diseases in your area' (p<0.01) as well as 'Alerts for mosquito "season" (p=0.013) had significant associations with the willingness to participate.

8 Discussion

This study emerged from my personal curiosity of the recurring dengue problem in Singapore, when a Global Mosquito Alert Consortium (GMAC) is being set up to utilise citizen-science networks for mosquito monitoring. As Singapore is often being cited as a world leader in *Aedes* control (Egger et al., 2008), I wanted to investigate if there would be a possibility to incorporate public participation in current surveillance and control methods. The research questions were formulated to first get a clearer picture of current surveillance and control methods; followed by investigating preventive behaviour against mosquitoes and mosquito-borne diseases and the motivations behind this behaviour in residents in Singapore. In addition to that, I analysed an existing citizen science mosquito-related project to see the usefulness and benefits of a citizen-science approach. Various stakeholders, including the public were involved, to gain an insight into their opinions and willingness to participate in a citizen science initiative, before arriving at the ultimate goal of this project which is how a citizen science project can be organized in Singapore to help with mosquito monitoring efforts.

This chapter is organized in five sections, with each section discussing the results from the previous chapters; discrepancies (if any) and limitations; and reflects upon the methodology and the research findings in the grand scheme of things.

8.1 Current surveillance and control methods

Singapore's efforts in mosquito surveillance and dengue control has often been lauded as top-notch and has even been cited as a world leader in *Aedes* control for decades (Egger et al., 2008). While these efforts have resulted in the reduction of the *Aedes* mosquito house index, Singapore still experiences occasional outbreaks of dengue. Thus, in this section, I will discuss some issues regarding current control and surveillance measures that are in place and how they can possibly be improved with a citizen science initiative.

Firstly, Singapore is well-known as a role model in the area of mosquito vector control. However, her status as a role model did not come cheap. According to an article written by Professor Tikki Pang for The Straits Times²⁵, Singapore's mosquito control efforts have amounted to half a billion US dollars over the past decade. Yet even so, Singapore still occasionally experience outbreaks of dengue and most recently, Zika too. This is probably due to the fact that there are still mosquitoes breeding in homes that go undetected. These undetected mosquitoes likely are the mosquitoes that are causing the dengue outbreaks in housing estates. Once the outbreak occurs, the mosquitoes are already one step ahead of the authorities and agencies. As it is impossible for NEA officers to conduct house visits around Singapore on a daily basis, the next best thing is allowing citizens to report mosquito nuisance or biting and even dengue-like symptoms (like the *FluMob* application developed by Prof May Lwin and her team). However, a potential obstacle to this would be the imposition of a fine should mosquitoes be caught breeding in homes.

Secondly, while the invention of Gravitraps has helped greatly with control and surveillance efforts, the use of Gravitraps as a cost effective tool is not without challenges. Lee et al. (2013) highlighted that the timing of deployment of Gravitraps is crucial – if deployed too early, it would result in resources being spread thinly and on the other hand, it might be ineffective if deployed late. A citizenscience approach can help to overcome this challenge. During my interview with Dr Christina Liew at EHI, I asked about the possibility to involve the public to host these Gravitraps (personal communication, 23 August 2017). NEA and EHI can equip volunteers with these Gravitraps and send out notifications as and when they think the time is right. This will no doubt help save time and

48

²⁵ Pang, T. (2015, July 24). Act against dengue now with tools that exist. Retrieved March 16, 2018, from http://www.straitstimes.com/singapore/environment/act-against-dengue-now-with-tools-that-exist

resources on the agencies' end. However, according to the team at EHI, they have yet to get the public to host these Gravitraps as they worry that such traps will become breeding grounds if not handled properly (personal communication, 23 August 2017). Although this might be the case, with the right education and training for interested participants, it could be a win-win situation. Volunteers would be able to handle these Gravitraps, thus being able to protect themselves while at the same time contributing towards surveillance and control efforts; while the agencies will be able to get their mosquito data from the mosquitoes that are successfully trapped.

Thirdly, the mobile applications (apps) available to report on mosquito nuisance and mosquito breeding spots are not yet quite well known amongst people in Singapore and the presence of different apps might confuse people. From my survey, only 37 (11.6%) respondents were aware of existing mobile applications or websites that allowed for people to report mosquito nuisance or breeding grounds (see Appendix B). 32 out of 37 of these respondents correctly listed either myENV or OneService or iTown@SG as platforms where they can report mosquito nuisance or breeding. This result shows that not many people are actually aware of the presence of such mobile applications. However, at the point of writing this report, I was unable to get information on the number of users for each of the app and how often mosquito nuisance/breeding was being reported. To make people more aware, there is a need to look into why the take-up rate is so low for these mobile phone applications. The various agencies involved could also look into utilizing different (media/non-media) channels to outreach to more people, and make known the presence of such applications.

In addition to this, the presence of different apps that enable people to report mosquito breeding spots and mosquito nuisance can have its downsides and upsides. At the point of writing this thesis, how NEA and MSO communicate with regards to the mosquito reports that are submitted via myENV and OneService respectively, is unclear. The downside that I observe from having different apps is that it probably confuses people, especially since the types of report to be submitted is not entirely similar. This also makes it hard to compare the data collected. Thus, it would be good if both agencies can collaborate and align the type of reports the public can submit. On the other hand, the upside is that both apps do not concentrate solely on reporting about mosquitoes. The myENV app covers topics like pollution control and meteorological information while the OneService app allows users to report all kinds of municipal issues. Having two different apps with different functions can help to attract and cater to more people with different preferences. The benefits of covering a variety of topics is evident in the example of the Dutch website 'Nature Today'. Nature Today covers all kinds of developments in nature, from mosquitoes, to flowering trees to wolf sightings, both locally in the Netherlands, and internationally. With this wide coverage of topics, Nature Today has been able to amass a huge following, both nationally and internationally.

Lastly, as can be seen from various control and surveillance methods in Chapter 3, almost everything is top-down, organized and conducted by governmental agencies. Even though Singapore combines the WHO's recommended strategies for control activities, which includes community education and participation, the bulk of the control strategies are still being carried out by the authorities. In a study by Dumont & Thuilliez (2016), their model on human behaviours and mosquito control produced several scenarios which resulted in external interventions generating perverse incentives. One such perverse outcomes is that households may reduce efforts to protect themselves and eliminate mosquito breeding sites in response to the control efforts carried out by public agencies/government. This will eventually render the efforts by public agencies useless, and cause the mosquito numbers to increase again (Dumont & Thuilliez, 2016). Another study, which looked into folk knowledge about dengue and mosquitoes, found that there were people that did not think they were at risk of dengue and left control activities to the relevant authorities to handle (Phuanukoonnon, Brough, & Bryan, 2006). These examples show that there is a need to engage the public more and increase citizen participation. If everything is done in a top-down approach, people might get complacent and think

that everything will be handled by the government and that they do not have to do anything to protect themselves. In addition to this, as seen in the results of my online survey, there is a huge group of respondents who are willing to participate in a citizen-science approach. This presents an opportunity to get society involved. This group of willing participants were also more aware (than those that were not so willing to participate), that keeping mosquitoes away is a shared responsibility between the various agencies as well as the individual. A citizen-science approach can thus help make more visible the efforts of the various agencies, by providing a platform for information sharing and dissemination by the agencies. Consequently, this large group of willing respondents will be able to see that the various agencies are indeed taking responsibility to keep mosquitoes away. This reinforces their belief that mosquito control is a joint effort and will be able to positively stimulate them to do their part too. Thus, a citizen-science approach can create a positive feedback loop, foster trust and improve engagement between agencies and the public and provide a platform to disseminate information and raise awareness.

8.2 Factors influencing preventive measures

To my best knowledge, no studies have been done to understand public perception and preventive behaviour amongst residents in Singapore with regards to mosquitoes and mosquito-borne diseases (MBDs). Thus, the online public perception survey was carried out. The survey was designed with the Extended Parallel Processing Model (EPPM) as a basis for understanding individuals' reaction and response to health related messages. This section will discuss the results of the survey, possible reasons for any discrepancies between expectation and actual results, the limitations of the methodology, along with other takeaways from the results of the analysis.

Firstly, I ranked the preventive measures according to how frequently they were being carried out. The preventive measure with the highest score was 'eliminating standing water containers', followed closely by 'use of air-conditioning/fan' and 'covering water storage'. Both 'eliminating standing water containers' and 'covering water storage' are part of the '5-Step Mozzie Wipeout' which came up in the top five. This would mean the campaign efforts of NEA have worked and that residents are diligently carrying out the '5-Step Mozzie Wipeout' to remove any potential mosquito breeding spots in their homes. The preventive measure with the lowest mean score was 'sleeping under mosquito bed net'. This could be due to the fact that Singapore has quite a warm and humid climate and sleeping under the bed net might make it warmer. In addition, from personal observations and experiences, it is only babies or young toddlers that are more likely to sleep under mosquito bed nets.

Next, the bivariate analysis between the preventive measures listed in the survey showed that many preventive measures correlated significantly. Each preventive measure listed, had at least one other (positive) significant correlation with another preventive measure. This shows that respondents do not only carry out one particular preventive measure by itself, but instead do a variety of other preventive measures too. The results of this particular bivariate analysis, along with the other results where 92.8% of respondents think 'Dengue is a serious disease' and 71.5% 'worry about contracting mosquito-borne diseases in Singapore', hints that people residing in Singapore are actually worried about mosquitoes and contracting mosquito-borne diseases. This is also evident in the significant (positive) correlation between 'Perceived Severity' and 'Perceived Susceptibility', meaning that the higher the perceived magnitude of the threat, the higher the perceived susceptibility of the individual. With this perceived severity and susceptibility present, I conclude that there is a perceived threat amongst residents in Singapore with regards to mosquitoes and mosquito-borne diseases.

Having established the frequently practised preventive measures, I then looked into the various EPPM categories with these preventive measures, in hopes to see if there is any explanation on what drives the preventive behaviour. When I tested 'Preventive Measures' on the whole with several of the EPPM categories, I expected to see some correlations with some of the categories. Studies have shown that

taking action in the form of preventive behaviour has a link with the perception that there is a threat (Thompson et al., 2018) and also a link with the level of self-efficacy one has in carrying out the measures (Isa, Loke, Smith, Papageorgiou, & Hunter, 2013). However, there were no significant correlations that came out of the bivariate analysis. This could be due to the fact that the "Preventive Measure" score is derived by using the average score of the aggregate of all the various preventive measures. As not all preventive measures would have a correlation with the different variables, aggregating the scores would result in the loss of significance along the way. This is evident in Table 8, where testing the individual preventive measures against the different EPPM categories, resulted in the presence of more significant correlations.

The results in Chapter 4, show that different correlations exist between the various preventive measures and the different statements in the EPPM categories. For the discussion of the results in this chapter, I will focus on the preventive measures of 'Using insect repellent on skin' and '5-Step Mozzie Wipeout'. I picked these two measures as they are both in the top five when the preventive measures were ranked, and also because both are different forms of control – insect repellent for preventing mosquito bites and '5-Step Mozzie Wipeout' to prevent mosquitoes from breeding within homes.

From the results of the survey, both the '5-Step Mozzie Wipeout' and the 'use of insect repellent' recorded significant positive correlations with people worrying about contracting MBD. This means that the more people worry about contracting MBD in Singapore, the more they will carry out the 5-Step Mozzie Wipeout and use insect repellents on their skin. However, when investigating the correlation with vulnerability to MBD, only the 'use of insect repellent' recorded a (positive) correlation with 'I am vulnerable to MBD'. This means that the more people feel that they are vulnerable to MBD, they are more likely to use insect repellent on their skin. This result makes sense because mosquito-borne diseases are transmitted by mosquitoes, and using insect repellent is a measure to keep mosquitoes away and from biting them. As for self-efficacy statements, both the '5-Step Mozzie Wipeout' and the 'use of insect repellent on skin' recorded correlations with 'I am confident that I can prevent myself from getting dengue/Zika'. However, while '5-Step Mozzie Wipeout' had a strong positive correlation, the 'use of insect repellent on skin' had a significant negative correlation. These results mean that the more people are confident in preventing themselves from getting MBD, they are more likely to carry out the 5-Step Mozzie Wipeout, and less likely to use insect repellent on their skin. This could mean that people do not associate using insect repellent on their skin with them being able to prevent themselves from getting MBD. This could be attributed to the fact that when agencies promote preventive behaviour, the focus is on the 5-Step Mozzie Wipeout. As this is with regards to healthcare and is communicated by the relevant agencies in-charge, people trust that it will help prevent them from getting MBD (Goh, 2017). The same cannot be said for the use of insect repellent, as it is not promoted in the campaigns against mosquitoes by the agencies. This reasoning could also explain the results of the two preventive measures with response efficacy, where only '5-Step Mozzie Wipeout' recorded a significant positive correlation.

Having seen the numerous correlations present with '5-Step Mozzie Wipeout' and 'Using insect repellent on skin' with the various statements under the different EPPM variables, the next step was to look into the step-wise regression between the individual preventive behaviour and the EPPM variables. However, only the '5-Step Mozzie Wipeout' will be discussed here because it recorded significant results. From the step-wise regression, I observe that the two categories that contributes significantly towards 5-Step Mozzie Wipeout is severity and self-efficacy. This means that '5-Step Mozzie Wipeout' is being carried out because people think that MBD is a threat and also because they are confident that they can carry it out to protect themselves from mosquitoes. This is in line with the EPPM, as in the model, it predicts that if there is a perceived threat, and there is perceived efficacy in the preventive measures introduced, the outcome will be that people will go into 'danger control process' and carry out the preventive behaviours. The final model also suggests that increasing 'self-

efficacy' and 'severity' can increase the frequency in which people carry out the preventive behaviour. Thus from these results, the challenge would be to look into how to increase the perception of severity and self-efficacy to get more people to carry out the preventive measures. While the perception of severity is already present in people, as seen from the results of the survey, the next thing would be to increase the confidence in people, to increase their levels of 'self-efficacy'. This is where a citizen-science approach can be helpful to raise self-efficacy levels. Once a citizen science project has been established, volunteers can be trained to submit data, and also be equipped with information on how to protect themselves. These volunteers can then go on to spread the information through word-of-mouth with their family and friends. This will definitely help in raising the confidence in people with regards to preventive behaviour as they will see that if their family or friends can do it, so can they. However, when designing communication strategies, it is also important to take note of the various perceptions of threat and efficacy levels. Different communication strategies based on the varying degree of perceived threats and efficacy can be used to help guide the designing of information for dissemination (Figure 23).

	HIGH EFFICACY Belief in effectiveness of solutions and confidence to practice them	LOW EFFICACY Doubts about effectiveness of solutions and about one's ability to practice them
HIGH THREAT Belief that the threat is harmful and that one is at risk	DANGER CONTROL People take protective action to avoid or reduce the threat. Strategy: Provide calls to action	FEAR CONTROL People are too afraid to act, just try to reduce their fear and feel better. Strategy: Educate about solutions
LOW THREAT Belief that the threat is trivial and that one is not at risk	LESSER AMOUNT OF DANGER CONTROL People know what to do but are not really motivated to do much Strategy: Educate about risk	NO RESPONSE People do not feel at risk, and do not know what to do about it anyway. Strategy: Educate about risk and about solutions

Figure 23. Communication strategies based on the Extended Parallel Processing Model (EPPM). (Adapted from http://www.healthcommcapacity.org/wp-content/uploads/2014/09/Extended-Parallel-Processing-Model.pdf)

Having discussed the results, there is a need to point out that this study has some limitations that should be taken into account when trying to decipher the results. As with any survey that consists of self-reports of preventive behaviour, there is some uncertainty embedded within the results as we do not know if the participants actually carry out the behaviours in their everyday life. In a paper by Flamand, Fritzell, Obale, Quenel, & Raude (2017), it was highlighted that self-reported behaviours could be subjected to social desirability effects - that they report carrying out certain type of behaviour as they think that that is what society expects of them. In order to be truly sure of the results of self-reported behaviour, the only way is to conduct experiments to monitor peoples' lives. However, as that would infringe on the privacy of their lives, the benefit of the doubt is exercised in this area. Furthermore, it is important to note that as this group of participants constitute a convenience sample of residents in Singapore, it might not be completely representative of the whole Singapore population. However, despite this limitation, the results of this survey do have importance. This is so as to the best of my knowledge, there are no other studies in relation to the perceptions of threat and efficacy levels done in Singapore with regards to mosquito-borne diseases. The results of this survey can serve as the first step to better understand the preventive behaviours of residents in Singapore, as well as the factors that influences them to act and perform preventive behaviour. Future research can also be done to better understand how and what affects the confidence level of people, which ultimately affects self-efficacy and can help guide future campaigns and communications that promote preventive behaviour.

8.3 Evaluation of the Dutch mosquito citizen science network

To understand how a citizen science network can contribute to science, the Muggenradar data from citizen's reporting was studied alongside a mosquito nuisance prediction model. Prior to the analysis of the results, the initial expectation was that the temporal variation in nuisance levels reported would be similar to the variation of mosquito nuisance as predicted by the model. Unfortunately, when the submitted nuisance reports were scored and analysed alongside the results of the prediction model, the results of the analysis did not comply with my initial expectations. The lack of compliance between the two datasets could be due to limitation of the model and some limitations of the citizen-science approach taken. This non-compliance does not mean that there is no value in a citizen-science approach, but rather that more can be done to make citizen science reported data be even more valuable and useful for science. This section will discuss the results, possible reasons for the discrepancies between expectation and the actual result, along with other lessons that can be learnt from the results of this analysis.

The results of the analysis have showed that when there is media attention or appearances, the counts of reported nuisance increases greatly as the Muggenradar team uses it as an opportunity to remind people to submit mosquito nuisance reports. However, the counts will start to decrease after sometime after the media appearance/attention. This trend is also observed in other citizen science projects like Mosquito Alert, where frequency of reporting has been observed – "reporting propensity decreases over time, and a possible explanation is that participants forget about the project" (Palmer et al., 2017). This result is important as it shows that is a large group of people willing to participate in citizen science but there is also a constant need to engage them. In a paper by van Vliet, Bron, & Mulder (2012), it highlights that communication with the public at large is an important aspect of any citizen science project. Active communication enables a greater outreach. A greater outreach in turn makes the public more aware of the project's existence (increases participation) and also provides an opportunity for generation of new ideas, partnerships and increase information transfer, awareness and even stimulate behavioural changes in the general public (van Vliet et al., 2012). Media attention/appearances are also opportunities to remind the public who have submitted reports before to continue to do so, regardless of whether mosquito nuisance was experienced. By engaging the media and thus the public, it will increase the number of reports submitted, and this might help bring in more reports, enough to study the spatial and temporal trends of mosquito nuisance.

Based on the results, there were some patterns between the variations within the nuisance score and the predicted nuisance in some months. Even though there were only a few patterns, these patterns provide insight into the temporal variation in mosquito nuisance that the public reports and can be used as a form of validation for the model. However, these patterns were not consistent all the time and it could be due the limitations of the prediction model. The prediction model used in this analysis only takes into consideration meteorological parameters, without any inclusion of mosquito population size or mosquito presence. This explains why there was a seasonal pattern observed in the graphs generated. The lack of a parameter to account for the presence/absence of mosquitoes means that even if no mosquitoes are present, the model would still predict the presence of mosquito nuisance. Thus to further improve this model and make it more comparable with citizen scientists' submitted data, incorporating mosquito population parameters would be good.

The other limitation that contributes to the lack of compliance between the two data sets lies in the methodology. Firstly, the method of taking the average of the total nuisance scores (weekly/monthly) to produce a graph as well as the simple summation of all the weather parameters to produce the predicted nuisance, is too simplistic as there could be other factors involved that might affect the accuracy of both the predicted nuisance and reported nuisance. Secondly, there is also subjectivity embedded in the nuisance reports that people submit as different people have different perceptions of what is considered "no nuisance" or "little nuisance" and "too much nuisance". In addition to the

first two points, the lack of consideration of spatial data (i.e. location of reports) could also affect the results. As the Netherlands is a big country, the mosquitoes could be present in some but not all places, and this would affect the nuisance reports as an average is taken to calculate the nuisance scores. Similarly, for the prediction model, the weather parameters represent the average for the whole of the Netherlands, which might not be fully representative for certain parts and thus lead to uncertainties in the prediction. To target this limitation, the methodology could be further developed to account for other variables. In addition, a more comprehensive research could be done to study the patterns of individual persons' reports, to see how to balance out the subjectivity in reports. Segregating the data collected according to location would also be more appropriate as it will show if different spatial patterns significantly differ from the average.

Other limitations include the way the system is being set up for people to report. There is currently no structured timing for people to make reports, it is up to the public's discretion as to when they want to submit a report. More often than not, this results in people only submitting reports when they experienced mosquito nuisance, thus neglecting to submit 'no nuisance' reports. This could be due to the fact that people are unaware of the usefulness of reporting 'no nuisance' and think that only presence of mosquito nuisance is worth reporting. Due to this lack of a structured reporting timing for mosquito nuisance and the public not actively submitting 'no nuisance' reports, it makes it difficult to compare the results to get a complete picture of how the variation in mosquito nuisance is like. To target this limitation in the set-up, it would be useful to gather a core group of volunteers that are willing to diligently submit nuisance reports. There should also be a structured reporting timing set at different times of the day to gather responses from these volunteers as well as the public, and everyone should be reminded that there is an option to submit 'no nuisance' if they did not experience any nuisance.

While there are limitations embedded in the methods and analysis, this is the first time that the data collected from Muggenradar is being analysed alongside a prediction model. Thus, even though there were no significant patterns to be observed, it provided some valuable insights on what has been done so far and some learning points for further improvement. With some modifications and adjustments, it shows that a citizen-science approach can provide useful spatial and temporal variation trends that can help with back up surveillance efforts and guide control measures. Another advantage that comes with such mosquito-monitoring citizen science project is the ability to have more information with regards to human-mosquito encounter probabilities, which is useful in countries and areas that have mosquitoes that can transmit diseases to humans (Palmer et al., 2017).

8.4 Stakeholders' perception of a citizen-science approach

Interviewing the various stakeholders involved in the mosquito scene in Singapore was an insightful experience. The opportunity to interview them gave me some thoughts on starting or intensifying current citizen science efforts in Singapore. It was heartening to see that most of the stakeholders were optimistic about a citizen-science approach. I picked out four main points for discussion:

- 1. The added value of a citizen-science approach;
- 2. Attracting people to get on board the project;
- 3. Ensuring the sustainability of citizen-science approaches; and
- 4. The type of information wanted from such a citizen-science approach.

8.4.1 Added value of a citizen-science approach

Dr Alex Cook, who helped with building a model to forecast dengue outbreaks in Singapore, mentioned that there are already extensive efforts in place to target the mosquito problem. In addition, he said that the NEA and MOH have already a lot of data available. Therefore, he does not think a citizen-science approach will help, especially in improving the prediction of dengue occurrence. Furthermore, he thinks that the forecast model is already good enough and "does not think that the

prediction of the models can get any better even with minor errors" because those errors are either due to randomness or inability to predict. While I think that the system in place to collect and manage data as well as forecast dengue outbreaks in Singapore is as good as the stakeholders have mentioned, I still believe that there is room for more to be done. (Seltenrich, 2016) wrote that the model, developed by Dr Cook and his team, had a potential shortcoming in that the model is unable to deliver daily, location-specific results that are useful to medical personnel and policymakers in bigger regions. In the same article (Seltenrich, 2016), Dr Ng Lee-Ching, who is the director of NEA's EHI and is part of the team that created the prediction model with Dr Alex Cook, was also quoted that "(they) are improving the accuracy of the model and increasing the spatial resolution to risk-stratify areas for targeted response". I believe that this presents an opportunity to use citizen science collected data to help strengthen the models that study mosquito dynamics. In the Netherlands, a study by Garcia-Martí, Zurita-Milla, van Vliet, & Takken (2017), used volunteered data to model and map tick dynamics. In their project, geospatial data provided by volunteers was incorporated into their model to study tick dynamics. As a result of this, the data was able to support scientific analysis and map tick dynamics on the national level, on a daily basis. As such, I believe that utilizing a citizen-science approach can help the team to monitor more specific areas and help with the team's ground-sensing efforts. With more hands and eyes on the ground, especially within people's homes or the areas they frequent, a citizen-science approach might inform the various stakeholders of places they might never think to look or consider. This view is also supported by Peters, Eames, & Hamilton's (2015) paper on the value of citizen science data. Peter's research revealed that one of the values of a citizen science project is the fact that the data comes from people that are on the ground every day. These people are more familiar with their surroundings and would be the "best people on the ground to monitor and understand changes to (their surroundings)". In the same project, interviews with staff from various agencies also mentioned using citizen science data to complement species distribution data through online and public databases to have a better understanding of the species distribution (Peters et al., 2015). As with anything new, it might require some time for people to be convinced of a citizenscience approach, but if thought out carefully and properly, a citizen science network and approach can prove to be a powerful resource for science and society.

Furthermore, it can be seen that some stakeholders and researchers like Prof May Lwin and her team, are keen on trying out a citizen-science approach. Even though MoBuzz was not introduced in Singapore, they actually have another project, FluMob, that is an application-based surveillance system. FluMob is currently being tested and used by health-care workers to report weekly if they have influenza-like symptoms with a smartphone. The future development of FluMob incudes the addition of "health education messaging and communication" as well as rolling out the system for public use, in order to be prepared in case an influenza outbreak occurs (Lwin et al., 2017). This example shows that there are stakeholders that see the potential in a citizen-science approach – to gather as well as disseminate information – and that they are willing to give it a try. This could also be used to complement Singapore's move towards a being Smart Nation²⁶.

8.4.2 Attracting people to participate in citizen science projects

In the interview, Prof May Lwin shared on her experiences with MoBuzz. One of the potential challenges that she mentioned was the high inertia and reluctance of the targeted users (in this case, the Public Health Inspectors) to try the MoBuzz application as an alternative form of data collection. However, she mentioned that with training and peer-to-peer sharing, the Public Health Inspectors grew more confident in their ability to use the application and the take-up rate increased. Similarly,

-

²⁶ Smart Nation is Singapore's vision to be an economically competitive global city and a liveable home. It is a whole-of-nation movement to harness digital technologies to build a future Singapore, to improve living and build a closer community, empower citizens to achieve their aspirations through good jobs and opportunities, and encourage businesses to innovate and grow. Information retried from: https://www.smartnation.sg/

with a citizen-science approach, I foresee that this will be one of the challenges, that there will be some initial hesitation, as with taking up anything new. However, with the correct communication style and message designed for various groups of people, it should be able to attract the public to participate. In an article by Raddick et al. (2013), it was mentioned that there is a need to understand volunteers' perspective of citizen science. With this understanding, there would be a clearer picture of volunteers' motivations to participate and what they hope to get out of their participation. Following this recommendation by Raddick et al. (2013), the results from the analysis in Chapter 7, can be used by organizers would be able to design their publicity materials as well as the project in a way that it would attract volunteers to participate. Martin, Christidis, & Pecl (2016) also noted that it is important to ensure that there are minimal barriers (e.g. too costly, too time-consuming or require too much knowledge that volunteers might not have) to first-time participants and that their needs and interests should be met in order to attract new participants.

Furthermore, if the project is able to gather a core group of volunteers and provide proper training, these trained volunteers can go on to spread the word to their families, friends and people living around them. This will help to increase the outreach as well as instil confidence in other potential users – once they see that their fellow family member or friend or neighbour is able to use the app or carry out certain preventive behaviour, the potential user might be convinced that he/she is able to do it too. Another way to attract people would be via societal publications. Societal publications in this case refers to the use of newspaper articles, television appearances, presentations at community events, online new channel and even social media. In a paper by van Vliet, Bron, & Mulder (2014), they showed that active communication through societal publications helped to attract and recruit many volunteers for their citizen science monitoring projects.

8.4.3 Ensuring sustainability of citizen-science approaches

Another challenge brought up by Prof May is with regards to the sustainability of such citizen science networks. As Prof May and her team were planning the next steps of MoBuzz, which includes rolling it out for public use, her team highlighted that sustainability would be a challenge – how to keep the public engaged and get people to use and share information, as well as to ensure that the public remains vigilant even in times when there is no potential threat being forecasted. The latter part is also highlighted by Dr Christina Liew of EHI, who mentioned that her team worries about campaign fatigue of the "5-Step Mozzie Wipeout". This is no doubt a challenge that would present itself with every project and campaign. However, it can be seen with the example of Muggenradar, that there is a need for constant media attention as well as appearances to ensure that the public is made aware of the existence of the project as well as serving as an opportunity to request for the public to submit nuisance reports. This is evident in Figure 24 where it can be seen that there are peaks of nuisance reports recorded when there is media attention and/or appearances. This is supported by the article in van Vliet et al. (2014), where it is also mentioned that societal publications can help with the retention of volunteers as well as dissemination of information and instructions to maintain the sustainability of citizen science projects.

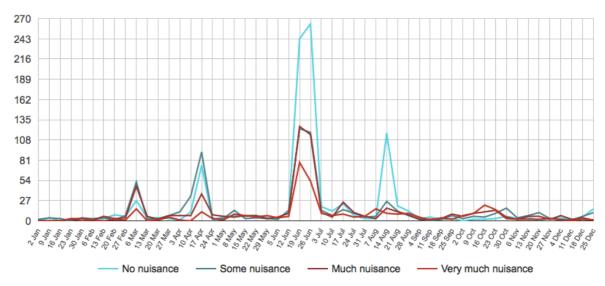


Figure 24. Muggenradar data on counts of nuisance reports / observations on a weekly basis for 2017. (Retrieved from <a href="https://www.naturetoday.com/intl/en/observations/mosquito-radar/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations/mosquito-radar/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations/mosquito-radar/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations/mosquito-radar/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations/mosquito-radar/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase="https://www.naturetoday.com/intl/en/observations2/nuisance-overview/?groep=36&soort=5083&jaar=2017&fenofase=3683&jaar=2017&fenofase=3683&jaar=2017&fenofase=3683&jaar=2017&fenofase=3683&jaar=2017&fenofase=3683&jaar=2017&fenofase=3683&jaar=2017&fenofase=36

In addition, since volunteers have been attracted to participate in citizen science projects, to keep them involved, there is a need to ensure that their needs and interest for participating are met and fulfilled. For example, according to the results in Chapter 7 on the factors that influence participation, it can be seen that people are willing to participate as they would like to have information about the mosquito seasons as well as information on how to protect themselves from mosquitoes. Thus, organisers should take note and reward their volunteers with this information in order to retain their volunteers. This point is supported by Wald, Longo, & Dobell (2016), where they found that citizen science programs that were able to meet the needs of volunteers' motivation to participate were better able to sustain the engagement and retention of their volunteers.

8.4.4 Type of information wanted from a citizen-science approach (by stakeholders)

With regards to information wanted by researchers and government agencies, it can be seen from the interviews that most of the stakeholders are keen on a citizen-science approach. However, as they all have their own areas of expertise and agenda, there is a need to be careful that the eventual data to be collected by the public is well within their abilities, otherwise, arrangements should be made to teach them how. As such, the involved stakeholders should sit together and decide what kind of information would be useful for each of them and brainstorm how to best get the information that they want without overloading the public, lest the public be deterred by the multitude of questions. In addition, with regards to science communication and society, Dr Alex Cook mentioned that most "Singaporeans on average are clued up about most things, but it is still quite a one-way street". By this, he means that the information transfer is mostly one way, and it is top-down, and it is difficult to know how much of this information transfer is being absorbed by the public. Hence, a citizen-science approach can help to change this, by considering the opinions of the public as well as serve as a way to gauge the public's level of awareness with regards to issues. In addition, as it is a citizen-science approach, there is a need to also consider what information volunteers, and this will be discussed in the next section.

8.5 Influencing participation in citizen science projects

Having studied the usefulness of citizen science collected data as well as received positive responses from various stakeholders on a citizen-science approach, the next step was to look into influencing the public to participate. In this section, I again used the information collected from the surveys to

analyse the potential factors that can help to influence and increase participation in citizen science projects. The results following the data collection and analysis will be discussed in this section, including any discrepancies and limitations with the methodology. The key takeaways from this section will also be included for consideration of the following section on how to organize a citizen science project.

Firstly, I looked into the factors that might influence participation. I tested respondents' susceptibility score with their willingness to participate. Prior to conducting the chi-square test, I expected a significant correlation between respondents' susceptibility and their willingness to participate. However, there was no significant correlation that came out of the chi-square test. An explanation for the lack of significance could be due to the susceptibility score being an average of the aggregate score of a few other statements. This is evident when I tested the individual statements under the 'Perceived Susceptibility' category, and the statement 'I am vulnerable to mosquito-borne diseases' recorded a significant correlation with willingness to participate. The rest of the statements under 'Perceived Susceptibility' category did not record any significant correlations when tested against willingness to participate. This could be due to the fact that the statements are not as clear and straightforward as the statement on 'I am vulnerable to mosquito-borne diseases'.

Another result with an unexpected outcome was that the chi-square result between mosquito nuisance experienced and willingness to participate. While the chi-square test revealed a correlation between the two, the numbers in the cross-tabulation was unexpected. With reference to Table 15, it can be seen that the largest group of participants are those that did not experience mosquito nuisance but yet are still willing to participate in a citizen science project on mosquitoes. A possible reason could be due to the way the question is phrased. Since the question surveyed respondents on the mosquito nuisance experienced in the past week, it is possible that at the time of completing the survey, the respondent did not yet experience any nuisance. It does not mean that these respondents completely do not experience any mosquito nuisance at all in their life. Additionally, this result could also be great for the project coordinators of a citizen science. If these people who did not encounter mosquito nuisance are also keen in participating in a citizen science project, their submission of "no nuisance" reports would also be important for data collection and analysis, as mentioned previously (see Section 8.3).

Next, I tested the question on whose responsibility it was to keep mosquitoes away and respondents' willingness to participate. Prior to the results, I expected perhaps only one or two options that will have significant correlations. However, the results from the chi-square test was surprising. Out of the five options that were given, four of these options ('Government', 'Town Council', 'Family Members' and 'Personal Responsibility') recorded significant correlations with willingness to participate. It is likely that because multiple options were allowed to be picked in this question, that there was more than one option that recorded a significant correlation. Upon closer inspection into the descriptive statistics of the given options, it can be seen that respondents who reported being willing to participate in a citizen science project, tended to pick at least three stakeholders for that question (multiplier factor = 3.49). For respondents that were not willing to participate, they tended to not pick more than three options. From the results, it can also be seen that respondents think that keeping mosquitoes away is a shared responsibility, and that most of them are willing to participate in a citizen science project, especially to learn how to better protect themselves and their loved ones (Table 18).

Table 18. Descriptive statistics of respondents' responses to who they thought was responsible for keeping mosquitoes away and their willingness to participate in a citizen science project.

Filters applied	Are you willing to participate in a citizen science project?						
Who do you think	All cases included (319 Respondents)		Filtered for cases where respondents answered "Yes" and "Maybe" (218 respondents)		Filtered for cases where respondents answered "No" (101 respondents)		
is responsible for keeping mosquitoes away?	Yes	No	Yes	No	Yes	No	
Government	184 (57.7%)	135 (42.3%)	134 (61.5%)	84 (38.5%)	50 (49.5%)	51 (50.5%)	
Town Council	228 (71.5%)	91 (28.5%)	166 (76.1%)	52 (23.9%)	62 (61.4%)	39 (38.6%)	
Pest Control Companies	131 (41.1%)	188 (58.9%)	94 (43.1%)	124 (56.9%)	37 (36.6%)	64 (63.4%)	
Family Members	215 (67.4%)	104 (32.6%)	155 (71.1%)	63 (28.9%)	60 (59.4%)	41 (40.6%)	
Personal Responsibility	300 (94%)	19 (6.0%)	211 (96.8%)	7 (3.2%)	89 (88.1%)	12 (11.9%)	
Total	1058	537	760	330	298	207	
'Multiplier'	3.32	1.68	3.49	1.51	2.95	2.05	

Another area that I looked into was the motivation people had to participate as well as the type of information they wanted. As citizen science projects is highly dependent on its volunteers, having insight into (potential and current) volunteers' motivations and needs can help with the strategies for recruitment and retention, and ultimately the success of the project (Kragh, 2016). From the results of the chi-square test, being able 'To learn how to better protect myself and my loved ones from mosquitoes and mosquito-borne diseases' was a motivation that recorded a significant correlation with willingness to participate. Similarly, information wanted on 'How to protect yourself and your loved ones from mosquitoes', 'When there are outbreaks of mosquito-borne diseases in your area' as well as 'Alerts for mosquito "season" also recorded significant correlations with willingness to participate. This result is in line with several papers, which reported that "self-directed motivations", such as personal interests are usually what influences people's (initial) participation (Kragh, 2016). However, there are also other papers that reported that contribution to project as well as the interest in the project topic are the most important motivational factors for participation (Land-Zandstra, Devilee, Snik, Buurmeijer, & Van Den Broek, 2016). From the various studies being conducted, as well as the responses from the survey, it can be seen that there are many different motivations for participation. It is thus important to know what these motivations are, to be able to attract people to participate, and ensure that the project meets the needs and motivations that people have, in order to retain them in the long run. With the results of the survey in mind, project coordinators can provide related information (e.g. how to protect against mosquitoes and MBD, alerts on outbreaks and mosquito seasons) as a form of reward for participation to attract and retain volunteers.

As part of the survey, I also surveyed the preferred communication channels as well as the types of information wanted by potential participants. With 99.4% of respondents having access to smartphones, it is no surprise that social media and mobile phone notifications were amongst the top channels that respondents preferred to receive information from. It was also reported in 2015 that Singapore was ranked first globally for smartphone penetration²⁷. With the ever increasing user rates of smartphones in the world, it presents an opportunity for citizen science projects to leverage on these technology to communicate with the public (Graham, Henderson, & Schloss, 2011). From the results of the survey, there is a correlation between mobile phone notifications as the preferred

_

²⁷ Smartphone penetration in Singapore the highest globally. (2015, February 11). Retrieved March 12, 2018, from https://www.todayonline.com/singapore/smartphone-penetration-singapore-highest-globally-survey

communication channel and willingness to participate. However, looking at the cross-tabulation table (Table 17), the number of participants willing to participate in a citizen science project is split down the line on 'Mobile phone notifications' as the preferred channel for receiving information. The implications of this results would be that if the eventual project's main mode of communication is by mobile phone notifications, there should be an option for users to adjust the settings as to whether or not they want to be sent notifications. This will accommodate respondents who may not like to receive notifications on their phone, but are still willing to participate.

9 Conclusion & Recommendations

Singapore has often been cited as one of the top countries in terms of mosquito surveillance and vector control. A lot of different projects and measures are currently in place to suppress mosquito populations as well as to continue surveillance efforts. However, as mentioned in the earlier chapters, the current surveillance and control efforts are mostly top-down approaches. The efforts are spearheaded by governmental agencies like NEA and its research lab, EHI. While there is community engagement and involvement in place, it is unknown how many people have been reached through these efforts and whether or not the message has been internalised by the public. Furthermore, from the results of the survey, it seems that people do perceive mosquito-borne diseases (MBDs) as a threat and they make conscious effort to take preventive measures to protect themselves. It can also be seen that the public trusts the government-recommended measures to protect themselves from mosquitoes and MBDs. Many of the respondents acknowledged that keeping mosquitoes away is a shared responsibility and that they are keen in participating in a citizen-science approach. In addition, the study of Muggenradar, has shown that citizen-collected data has the potential to add value to existing research. Through the example of Muggenradar, it has also shown that societal publications and media attention and appearances are key channels to outreach, attract and retain volunteers. Furthermore, the survey results have also shown that people are willing to participate in such projects in exchange for mosquito-related information as well as how to protect themselves. Thus, from the above mentioned points, there is a potential for the existing mosquito monitoring program in Singapore to be extended with a citizen-science approach.

From the interviews and surveys done, it was brought to my attention that mobile phone applications like myENV by NEA and OneService by MSO are already introduced. These apps allow people to report mosquito breeding spots (both myENV and OneService) and mosquito nuisance (myENV only). Besides mosquito-related reports, myENV enables its users to receive and report about their environment and OneService acts as a one-stop app that enables its users to report all sorts of municipal issues. The presence of two different apps can help to reach out to more people as well as cater to different user preferences. However, there are still a lot of people that are not aware of the presence of these apps and what they can do with the apps. As such, my recommendation would be to NEA (and MSO) to keep the existing apps and use them to build up a citizen science network, together with the following suggestions:

- Collaboration between agencies and harmonization of methodologies

It is not completely clear how the current communication between NEA and MSO is, with regards to the mosquito reports they receive on their respective apps. My recommendation would be for both agencies to collaborate with each other. They could also involve other stakeholders that are part of the "mosquito scene" in Singapore, e.g. the interviewees in this research project. There is a need to discuss the current state of things and find out exactly what information could help the various stakeholders (i.e. with regards to prediction models, mosquito surveillance or mosquito control etc). The information from the various stakeholders can help build the basis and purpose of the citizen science project. In addition, as both apps currently have different reporting strategies, there should be a harmonization and alignment in the way the reports are to be made. This would make the data collected from either app more comparable.

More structured system of reporting

With the results from the analysis done on the Muggenradar data, it is important to note that there is a need for a more structured system of reporting. As more people have access to smartphones, there lies an opportunity to take advantage of mobile technology and high numbers of smartphone users to create a more structured system of reporting. Agencies can engineer their respective apps to be able to send push notifications to app users at certain time of the day, to ask if the user has experienced mosquito nuisance. The user would just have to press a button to indicate the nuisance experienced

and the report will be considered submitted. The benefits of having such a structured system ensures that data collected is more comprehensive, both spatially and temporally. It also makes it easy for users to submit presence/absence of nuisance/biting reports and minimizes the tendency to only receive reports when people experience no nuisance. However, it should be noted that not all users might be keen on submitting daily reports even with the ease of use. As such, project coordinators can also establish a core group of volunteers who are willing to do this on a daily basis (e.g. collaborate with NEA's Dengue Prevention Volunteer Group). This core group of volunteers can simultaneously act as advocates for the project as well as help in information dissemination with regards to mosquitoes and MBD. Training can also be provided to them, to teach (e.g. to teach them how to host a Gravitrap in their own home) and equip them with information that they can share with the people around them (e.g. how to protect themselves from mosquitoes and MBD).

- Understanding motivations for participation

However, it is also important to remember that this is a citizen science project and is thus highly dependent on the public/volunteers. Such projects should be a "two-way street" and not solely top-down from the project coordinators. People's motivations for volunteering should be taken into consideration. As seen in the discussion in Chapter 7, people's initial motivations for volunteering is usually based on personal interests, i.e. what can they gain by helping out with the project. With this information, along with insights from the survey I conducted and other research, it can help the project coordinators have a better understanding of the motivations and plan their publicity to attract volunteers. In addition, the information that respondents stated they wanted out of such projects, should definitely be something that project coordinators should take note of. Providing volunteers with the information that they want could be a form of reward for their voluntary efforts, as well as to ensure retention of volunteers.

- Media and citizen engagement

As seen from the results, media has an important role to play in citizen science projects. With so many different media channels available, people of all ages can be reached. For example, the traditional medium of television, radio and newspapers can reach out to the older generations, while channels like social media, online websites etc can be used to communicate to the younger generation. Media can be used to promote the project and reach out to people of all ages. It can also be used to ensure sustainability by continuously sharing about the project as well as information that participants want i.e. how to protect themselves against MBD and alerts about mosquito seasons. As there might be varying skill levels of citizen science participants that might lead to inconsistencies in data collected, the media can be used to give clear instructions and expectations to participants, e.g. that submission of "no nuisance" reports is also important data. It would also be good to use the media to share about the "big picture" — about the data collected by the public and how it contributes to science, surveillance and monitoring. This will enable the volunteers to see how their efforts are contributing to the bigger picture of mosquito monitoring and control and build trust in the process.

- Receiving other forms of feedback

Besides just receiving mosquito data from the public, project coordinators should also be open to receiving feedback from the public. As no project is completely perfect, there is always room for improvement and advancement. By allowing the public to provide feedback, it may lead to new insights, and it will definitely help to instil a sense of ownership and trust in volunteers. It could also result in a change in the level of citizen science, from citizens being merely as sensors to citizens as interpreters or even towards a more participatory science, where the public is involved in problem definition and data collection (Figure 5).

In conclusion, as the mosquito problem is a complex one with many different factors involved, there is a need to make it as holistic and as comprehensive as possible. Having data sent by citizens can

provide insights into the nuisance and dynamics of mosquitoes. Though there might be doubts about the quality of data submitted by non-experts, as well as the subjectivity embedded within the submitted reports, a citizen-science approach presents an opportunity to enhance the current surveillance and control efforts. These submitted reports can be studied alongside the mosquito data (from NEA/EHI) has through Gravitraps, as well as with medical data (from the Ministry of Health) associated with mosquito-borne diseases. Together, these datasets will provide a better understanding into the dynamics of mosquito populations as well as mosquito-human interactions. As Singapore is considered a role model in the way mosquito surveillance and control is being conducted, if she is able to also incorporate a citizen-science approach into existing efforts, it might encourage other countries to follow suit as well. This also presents an opportunity for Singapore to be a part of the Global Mosquito Alert Consortium, to share best practices with regards to surveillance and control, and contribute to the global monitoring of mosquitoes.

10 References

- Dumont, Y., & Thuilliez, J. (2016). Human behaviors: A threat to mosquito control? *Mathematical Biosciences*, *281*, 9–23.
- Egger, J. R., Ooi, E. E., Kelly, D. W., Woolhouse, M. E., Davies, C. R., & Coleman, P. G. (2008). Reconstructing historical changes in the force of infection of dengue fever in Singapore: implications for surveillance and control. Bulletin of the World Health Organization. World Health Organization. Retrieved from http://www.who.int/bulletin/volumes/86/3/07-040170/en/
- Flamand, C., Fritzell, C., Obale, P., Quenel, P., & Raude, J. (2017). The Role of Risk Proximity in the Beliefs and Behaviors Related to Mosquito-Borne Diseases: The Case of Chikungunya in French Guiana. *The American Journal of Tropical Medicine and Hygiene*, *97*(2), 344–355.
- Garcia-Martí, I., Zurita-Milla, R., van Vliet, A. J. H., & Takken, W. (2017). Modelling and mapping tick dynamics using volunteered observations. *International Journal of Health Geographics*, 16(1), 41.
- Goh, A. (2017). Trust in Singapore Holds Steady. Retrieved March 12, 2018, from https://www.edelman.com/post/trust-singapore-holds-steady/
- Graham, E. A., Henderson, S., & Schloss, A. (2011). Using mobile phones to engage citizen scientists in research. *Eos, Transactions American Geophysical Union*, *92*(38), 313.
- Haklay, M. (2013). Citizen Science and Volunteered Geographic Information overview and typology of participation, 105–122.
- Hii, Y. L., Rocklöv, J., Ng, N., Tang, C. S., Pang, F. Y., & Sauerborn, R. (2009). Climate variability and increase in intensity and magnitude of dengue incidence in Singapore. *Global Health Action*, *2*(1), 2036.
- Isa, A., Loke, Y. K., Smith, J. R., Papageorgiou, A., & Hunter, P. R. (2013). Mediational Effects of Self-Efficacy Dimensions in the Relationship between Knowledge of Dengue and Dengue Preventive Behaviour with Respect to Control of Dengue Outbreaks: A Structural Equation Model of a Cross-Sectional Survey. *PLoS Neglected Tropical Diseases*, 7(9), e2401.
- Kampen, H., Medlock, J. M., Vaux, A. G. C., Koenraadt, C. J. M., van Vliet, A. J. H., Bartumeus, F., ... Werner, D. (2015). Approaches to passive mosquito surveillance in the EU. *Parasites & Vectors*, 8(1), 9.
- Kasl, S. V., & Cobb, S. (1966). Health Behavior, Illness Behavior, and Sick-Role Behavior. *Archives of Environmental Health: An International Journal*, 12(4), 531–541.
- Kragh, G. (2016). The motivations of volunteers in citizen science | The Institution Of Environmental Sciences. *Environmental Scientist*, 25.2. Retrieved from https://www.theies.org/analysis/motivations-volunteers-citizen
- Land-Zandstra, A. M., Devilee, J. L. A., Snik, F., Buurmeijer, F., & Van Den Broek, J. M. (2016). Citizen science on a smartphone: Participants' motivations and learning. *Public Understanding of Science*, 25(1), 45–60.
- Lee, C., Vythilingam, I., Chong, C.-S., Aliff, M., Razak, A., Tan, C.-H., ... Ng, L.-C. (2013). Gravitraps for Management of Dengue Clusters in Singapore. *Am. J. Trop. Med. Hyg, 88*(5), 888–892.
- Ler, T. S., Ang, L. W., Siew, G., Yap, L., Ng, L. C., Tai, J. C., ... To, C. (2011). Epidemiological characteristics of the 2005 and 2007 dengue epidemics in Singapore similarities and distinctions, *21*(21).
- Liew, C., & Curtis, C. F. (2004). Horizontal and vertical dispersal of dengue vector mosquitoes, Aedes aegypti and Aedes albopictus, in Singapore. *Medical and Veterinary Entomology*, 18(4), 351–360.
- Liew, C., Curtis, C. F., Agency, N. E., Liew, C., & Curtis, C. F. (2004). Horizontal and vertical dispersal of dengue vector mosquitoes, Aedes aegypti and Aedes albopictus, in Singapore. *Medical and*

- Veterinary Entomology, 18(4), 351-60.
- Lwin, M. O., Vijaykumar, S., Noel, O., Fernando, N., Cheong, S. A., Sampath Rathnayake, V., ... Foo, S. (2014). A 21st century approach to tackling dengue: Crowdsourced surveillance, predictive mapping and tailored communication. *Acta Tropica*, *130*, 100–107.
- Lwin, M. O., Yung, C. F., Yap, P., Jayasundar, K., Sheldenkar, A., Subasinghe, K., ... Ang, B. S. P. (2017). FluMob: Enabling Surveillance of Acute Respiratory Infections in Health-care WorkersviaMobile Phones. *Frontiers in Public Health*, *5*, 49.
- Martin, V. Y., Christidis, L., & Pecl, G. T. (2016). Public Interest in Marine Citizen Science: Is there Potential for Growth? *BioScience*, 66(8), 683–692.
- Ooi, E.-E., Goh, K.-T., & Gubler, D. J. (2006). Dengue prevention and 35 years of vector control in Singapore. *Emerging Infectious Diseases*, 12(6), 887–93.
- Oosterbroek, B. (2011). Towards a Model to predict Potential Mosquito Nuisance in The Netherlands.
- Palmer, J. R. B., Oltra, A., Collantes, F., Delgado, J. A., Lucientes, J., Delacour, S., ... Bartumeus, F. (2017). Citizen science provides a reliable and scalable tool to track disease-carrying mosquitoes. *Nature Communications*, 8(1), 916.
- Peters, M., Eames, C., & Hamilton, D. (2015). The use and value of citizen science data in New Zealand. Journal of the Royal Society of New Zealand, 45(3), 151–160.
- Phuanukoonnon, S., Brough, M., & Bryan, J. H. (2006). Folk knowledge about dengue mosquitoes and contributions of health belief model in dengue control promotion in Northeast Thailand. *Acta Tropica*, 99(1), 6–14.
- Potter, A., Jardine, A., & Neville, P. J. (2016). A Survey of Knowledge, Attitudes, and Practices in Relation to Mosquitoes and Mosquito-Borne Disease in Western Australia. *Frontiers in Public Health*, *4*, 32.
- Raddick, J. M., Bracey, G., Gay, P. L., Lintott, C. J., Cardamone, C., Murray, P., ... Vandenberg, J. (2013). Galaxy Zoo: Motivations of Citizen Scientists. *Astronomy Education Review*, 12(1).
- Seltenrich, N. (2016). Singapore Success: New Model Helps Forecast Dengue Outbreaks. *Environmental Health Perspectives*, 124(9), A167.
- Smolinski, M. S., Crawley, A. W., Olsen, J. M., Jayaraman, T., & Libel, M. (2017). Participatory Disease Surveillance: Engaging Communities Directly in Reporting, Monitoring, and Responding to Health Threats. *JMIR Public Health and Surveillance*, *3*(4), e62.
- Struchiner, C. J., Rocklöv, J., Wilder-Smith, A., Massad, E., Alphey, L., & Edman, J. (2015). Increasing Dengue Incidence in Singapore over the Past 40 Years: Population Growth, Climate and Mobility. *PLOS ONE*, *10*(8), e0136286.
- Tan, Y. S., Lee, T. Y., & Tan, K. (2009). *Clean, Green and Blue: Singapore's Journey Towards Environmental and Water Sustainability*. Institute of Southeast Asian Studies.
- Thompson, E. L., Vamos, C. A., Jones, J., Liggett, L. G., Griner, S. B., G. Logan, R., & Daley, E. M. (2018). Perceptions of Zika Virus Prevention Among College Students in Florida. *Journal of Community Health*, 1–7.
- van Vliet, A. J. H., Bron, W. A., & Mulder, S. (2014). The how and why of societal publications for citizen science projects and scientists. *International Journal of Biometeorology*, *58*(4), 565–577.
- Van Vliet, A. J. H., Bron, W. A., & Mulder, S. (2012). The how and why of societal publications for citizen science projects and scientists.
- Wald, D. M., Longo, J., & Dobell, A. R. (2016). Design principles for engaging and retaining virtual citizen scientists. *Conservation Biology*, *30*(3), 562–570.

- Witte, K., & Allen, M. (2000). A Meta-Analysis of Fear Appeals: Implications for Effective Public Health Campaigns. *Health Education & Behavior*, *27*(5), 591–615.
- Yoshikawa, M. J. (2013). Vector Control and Surveillance Operations in the Republic of Singapore. *Tropical Medicine and Health*, *41*(2), 61–66.

Appendix A – Interviewee List & Interview Guidelines

List of interviewees and their affiliations

#	Interviewee (Date)	Affiliations
1	Dr Julien Pompon (26 July 2017)	 Assistant Professor, Emerging Infectious Diseases Programme, Duke-NUS Medical School
2	Dr Alex Cook (26 July 2017)	 (Primary) Vice Dean (Research) and Domain Leader (Biostatistics & Modelling), Saw Swee Hock School of Public Health (Joint) Associate Professor at the Yale-NUS College, the Department of Statistics and Applied Probability, NUS Yong Loo Lin School of Medince, and the Program in Health Services and Systems Research at the Duke-NUS Graduate Medical School Singapore
3	Dr Hsu Li Yang (3 August 2017)	 Programme Leader (Antimicrobial Resistance), Saw Swee Hock School of Public Health Adjunct Associate Professor at NUS Yong Loo Lin School of Medicine Senior Consultant and Head, Department of Infectious Diseases, Tan Tock Seng Hospital Deputy Clinical Director, Communicable Diseases Centre, Ministry of Health
4	Dr Roman Carrasco (10 August 2017)	 Assistant Professor, Department of Biological Sciences, National University of Singapore (NUS)
5	Dr Ian Mendenhall (22 August 2017)	 Principal Research Scientist, Emerging Infectious Diseases Research Program, Duke-NUS Medical School
6	Prof May Oo Lwin (22 August 2017)	 Associate Dean (Special Projects), College of Humanities, Arts, & Social Sciences Director, University Scholars Programme Wee Kim Wee School of Communication and Information College of Humanities, Arts, & Social Sciences
7	Dr Christina Liew (23 August 2017)	Assistant Director (Partnerships), Environmental Health Institute (EHI), National Environment Agency (NEA)

<u>List of Interview Questions (General for all stakeholders)</u>

- 1. Open interview with general questions on their current research and what aspects of mosquitoes/MBD they are involved in. Examples include:
 - a. "What aspect of mosquito/mosquito-borne diseases are you studying?"
 - b. On your profile you state "Many entomological factors influence the transmission and therefore the epidemic potential of these viruses" what are some of these entomological factors?
- 2. What do you think are some factors that affects the mosquito populations?
- 3. Do you think enough is being done with regards to mosquito control in Singapore? Is there room for more improvement?
- 4. How big a problem do you think dengue is in Singapore? In your opinion, is this something that people should be constantly worried about?
- 5. How do you think the Singapore public perceives mosquitoes and mosquito borne diseases?
- 6. Do you know anything about citizen science? (Following which, introduce Citizen Science and explain about CS efforts in NL/Spain surrounding mosquito monitoring and upcoming Global Mosquito Alert)
- 7. Do you think that such a CS project will work in Singapore? Do you see it being beneficial for your research? Would you be interested in such a project? What kind of information would you like to have from such an initiative?
- 8. Where do you get funding from for mosquito related research? If from the state/government, is there enough support?
- 9. Do you think there is much communication between science and society in Singapore? Do you submit press releases to the media; do media people approach you or your colleagues for more information with regards to dengue and mosquitoes?

Appendix B – Online Public Perception Survey

MSc Thesis Survey - Citizen Science & Mosquito Surveillance

Key:

- Original document of the survey is in black.
- Numbers in parenthesis in black, is the output variable in the SPSS export from Qualtrics
- Statistics computed on SPSS are included into this survey in orange, e.g. [A, B%], where A is the count of respondents and B is the percentage of the total
- For questions where a score is tabulated for the category, the scores assigned are indicated in **blue**, e.g. (X), where X is the score assigned to each option in that sub question

Start of Block: Introduction

Q1 Hello! My name is Cassandra Tho and I am a Singaporean currently enrolled in Wageningen University in the Netherlands. I am doing my thesis on possibilities to involve the public in the surveillance and monitoring of mosquitoes in Singapore. Furthermore I aim to determine public perception with regards to mosquitoes and mosquito-borne diseases in Singapore. The survey should take you around 10-15 minutes to complete. Please be assured that this survey is fully anonymous and the results of this survey will be kept strictly confidential and will only be used for the purpose of my thesis.

Thank you in advance for your time and whenever you're ready, click the arrow button to proceed to fill out the survey!

End of Block: Introduction	
Start of Block: Knowledge pertaining to mosquitoes/MBD	
Q2 Do you know how a mosquito looks like? [319]	
O Yes (1) [315, 98.7%]	
O No (2) [4, 1.3%]	

Q3 What is most common mosquito species found in Singapore? [319]				
O Aedes aegypti (1) [215, 64%]				
O Aedes albopictus (2) [60, 188%]				
O Anopheles gambiae (3) [31, .7%]				
O Culex pipens (4) [13, 4.1%]				
Q4 From the following images, select all the options that shows a mosquito. [319] (Multiple answers possible)				
Image:Midge (1) [200, 62.7%]				
Image: Aedes aegypti (2) [296, 92.8%]				
Image:Crane fly (3) [59, 18.5%]				
Image:Blister beetle 1478x1027 (4) [3, 0.9%]				
Image:Anopheles sinensis (5) [258, 80.9%]				
Q5 How difficult is it to kill a mosquito? [319]				
Extremely easy - I always manage to kill them (1) [7, 2.2%]				
O Somewhat easy (2) [87, 27.3%]				
O Neither easy nor difficult (3) [92, 28.8%]				
O Somewhat difficult (4) [101, 31.7%]				
Extremely difficult - I always miss them (5) [32, 10%]				

Q6 In which locations are you usually being bitten by mosquitoes? [319] Multiple answers possible)					
In my house (1) [120, 37.6%]					
Outdoors on my property (e.g. porch, garden, backyard) (2) [139, 43.6%]					
At my workplace (3) [32, 10%]					
Nature parks/Park connectors (4) [266, 83.4%]					
Others, Please specify: (5) [19, 6.0%]					
- Anywhere & everywhere					
- Areas close to construction sites, factories, work sites					
- At bus stops					
- Void Decks (under HDB flats)					
- Non-air-conditioned places / outdoors					
- SAF (Singapore Armed Forces) training areas					
SAI (Singapore Armed Forces) training areas					
Of Do you think that all mosquitoes can transmit diseases? [319] Of Yes (1) [83, 26.0%] Maybe (2) [85, 26.6%]					
O7 Do you think that all mosquitoes can transmit diseases? [319] O Yes (1) [83, 26.0%]					
Of Do you think that all mosquitoes can transmit diseases? [319] Of Yes (1) [83, 26.0%] Maybe (2) [85, 26.6%]					
O7 Do you think that all mosquitoes can transmit diseases? [319] Yes (1) [83, 26.0%] Maybe (2) [85, 26.6%] No (3) [151, 47.3%]					
O7 Do you think that all mosquitoes can transmit diseases? [319] O Yes (1) [83, 26.0%] Maybe (2) [85, 26.6%] No (3) [151, 47.3%]					
27 Do you think that all mosquitoes can transmit diseases? [319] Yes (1) [83, 26.0%] Maybe (2) [85, 26.6%] No (3) [151, 47.3%] 8 Do you think that mosquito-borne diseases can lead to death? [319] Yes (1) [253, 9.3%]					

Q9 Can the following diseases be transmitted by the Aedes mosquito?

	Yes (1)	No (2)	Not sure (3)
AIDS (1) [319]	[44, 13.8%]	[229, 71.8%]	[46, 14.4%]
Chikungunya (2) [319]	[160, 50.2%]	[42, 13.2%]	117, 36.7%]
Dengue (3) [319]	[311, 7.5%]	[3, 0.9%]	[5, 1.6%]
Encephalitis (4) [319]	[57, 17.9%]	[74, 23.2%]	[188, 58.9%]
Influenza (5) [319]	[60, 18.8%]	[166, 52.0%]	[93, 29.2%]
Malaria (6) [319]	[229, 71.8%]	[49, 15.4%]	[41, 12.9%]
Meningitis (7) [319]	[60, 18.8%]	[109, 34.2%]	[150, 47.0%]
Zika (8) [319]	[284, 89.0%]	[17, 5.3%]	[18, 5.6%]

End of Block: Knowledge pertaining to mosquitoes/MBD

Start of Block: Experience with MBD in SG

Q10 How many people do you know have had Dengue/Zika/Chikungunya? [319]

- 0 (1) [0] [86, 27.0%]
- O 1 (3) [1] [71, 22.3%]
- **2** (4) [2] [90, 28.3%]
- 3 (5) [3] [33, 10.3%]
- **4** (6) [4] [5, 1.6%]
- 5 or more (7) [5] [34, 10.7%]

(Multiple answers possible)
Myself (1) [17, 5.3%]
Partner (Spouse/Boyfriend/Girlfriend) (2) [8, 2.5%]
Family/Relative (3) [69, 21.6%]
Friend (4) [170, 53.3%]
Colleague (5) [45, 14.1%]
Neighbour (6) [14, 4.4%]
End of Block: Experience with MBD in SG

Start of Block: Attitudes, Perception & Behaviour

Q12 What do you think about mosquitoes?

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)	I don't know (6)
I think mosquitoes are a nuisance (1)	[10, 3.1%]	[3, 0.9%]	[20, 6.3%]	[77, 24.1%]	[208, 65.2%]	[1, 0.3%]
Mosquitoes have a negative impact on the quality of my life (2)	[10, 3.1%]	[18, 5.6%]	[53, 16.6%]	[107, 33.5%]	[129, 40.4%]	[2, 0.6%]
Mosquitoes do not bother me (3)	[119, 37.3%]	[129, 40.4%]	[44, 13.8%]	[21, 6.6%]	[5, 1.6%]	[1, 0.3%]
I think the world will be a better place without mosquitoes (4)	[12, 3.8%]	[27, 8.5%]	[72, 22.6%]	[86, 27.0%]	[119, 37.3%]	[3, 0.9%]

Q13 Did you experience any mosquito nuisance (buzzing, biting) in the past week? (Multiple answers possible)

I did not experience any mosquito nuisance (1) [132, 41.4%]
I was bitten by mosquitoes this week (2) [144, 45.1%]
I experienced mosquito buzzing around me (3) [61, 19.1%]
Mosquitoes disturbed a night's rest (4) [30, 9.4%]

74

Q14 How often were you been bitten by mosquitoes in the past week? [319]	
O Daily (1) [8, 2.5%]	
O I got bitten on 1 day this week (2) [108, 33.9%]	
O I got bitten on 2-3 days of this week (3) [50, 15.7%]	
O I got bitten on 4-6 days of this week (4) [13, 4.1%]	
O I did not get bitten (5) [140, 43.9%]	

Q15 Please rate the extent to which you agree/disagree to the following statements: (Note: Mosquito-borne diseases refer to diseases such as Chikungunya, Dengue, Malaria, Zika)

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)	I don't know (6)
Dengue is a serious disease (1)	[1] [17, 5.3%]	[2]	[3] [6, 1.9%]	[4] [118, 37.0%]	[5] [178, 55.8%]	-
Zika is a serious disease (2)	[1] [17, 5.3%]	[2] [1, 0.3%]	[3] [10, 3.1%]	[4] [97, 30.4%]	[5] [194, 60.8%]	-
I worry about contracting mosquito-borne diseases in Singapore (3)	[1] [6, 1.9%]	[2] [25, 7.8%]	[3] [60, 18.8%]	[4] [145, 45.5%]	[5] [83, 26.0%]	-
If I get Dengue, it will not be more serious than other diseases (4)	[5] [34, 10.7%]	[4] [141, 44.2%]	[3] [71, 22.3%]	[2] [53, 16.6%]	[1] [9, 2.8%]	[missing value] [11, 3.4%]
If I get Zika, it will not be more serious than other diseases (5)	[5] [48, 15.0%]	[4] [145, 45.5%]	[3] [60, 18.8%]	[2] [47, 14.7%]	[1] [11, 3.4%]	[missing value] [8, 2.5%]
I think the Singapore healthcare system is well- equipped and able to treat mosquito-borne diseases (6)	[5] [5, 1.6%]	[4] [13, 4.1%]	[3] [66, 20.7%]	[2] [177, 55.5%]	[1] [47, 14.7%]	[missing value] [11, 3.4%]
I think the relevant agencies are doing a good job keeping mosquitoes away (7)	[5] [8, 2.5%]	[4] [21, 6.6%]	[3] [83, 26.0%]	[2] [162, 50.8%]	[1] [40, 12.5%]	[missing value] [5, 1.6%]

Q16 Please rate the extent to which you agree/disagree to the following statements:

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)	I don't know (6)
I am exposed to <i>Aedes</i> mosquitoes (1)	[1] [12, 3.8%]	[2] [40, 12.5%]	[3] [88, 27.6%]	[4] [134, 42.0%]	[5] [19, 6.0%]	[missing value] [26, 8.2%]
I am vulnerable to mosquito- borne diseases (2)	[1] [10, 3.1%]	[2] [34, 10.7%]	[3] [91, 28.5%]	[4] [152, 47.6%]	[5] [22, 6.9%]	[missing value] [10, 3.1%]
I am more likely to get Dengue than the people around me (3)	[1] [16, 5.0%]	[2] [94, 29.5%]	[3] [133, 41.7%]	[4] [31, 9.7%]	[5] [9, 2.8%]	[missing value] [36, 11.3%]
My immune system protects me from getting Dengue/Zika (4)	[5] [29, 9.1%]	[4] [103, 32.3%]	[3] [115, 36.1%]	[2] [31, 9.7%]	[1] [3, 0.9%]	[missing value] [38, 11.9%]
My past experiences make me believe that I am not likely to get Dengue/Zika even if my friends get it (5)	[5] [32, 10.0%]	[4] [138, 43.3%]	[3] [97, 30.4%]	[2] [24, 7.5%]	[1] [6, 1.9%]	[missing value] [22, 6.9%]
I am only at risk of getting Dengue in the rainy seasons (6)	[46, 14.4%]	[167, 52.4%]	[59, 18.5%]	[33, 10.3%]	[1, 0.3%]	[13, 4.1%]
I am only at risk of getting Dengue in the hotter months (7)	[38, 11.9%]	[136, 42.6%]	[71, 22.3%]	[54, 16.9%]	[7, 2.2%]	[13, 4.1%]

Q17 Do you use the following means to protect you and your loved ones from mosquitoes?

	Yes, often (1) [3]	Yes, sometimes (2) [2]	No, seldom (3) [1]	No, never (4) [0]	N/A (5) [Missing value]
5 Step Mozzie Wipeout (12)	[62, 19.4%]	[134, 42.0%]	[63, 19.7%]	[46, 14.4%]	[14, 4.4%]
Burn mosquito coils (13)	[10, 3.1%]	[53, 16.6%]	[87, 27.3%]	[157, 49.2%]	[12, 3.8%]
Covering water storage (2)	[168, 52.7%]	[97, 30.4%]	[20, 6.3%]	[19, 6.0%]	[15, 4.7%]
Eliminating standing water containers (3)	[211, 66.1%]	[87, 27.3%]	[9, 2.8%]	[4, 1.3%]	[8, 2.5%]
Installing insect screens on windows/doors (4)	[20, 6.3%]	[23, 7.2%]	[60, 18.8%]	[194, 60.8%]	[22, 6.9%]
Limiting outdoor activity during peak mosquito biting times (5)	[31, 9.7%]	[74, 23.2%]	[91, 28.5%]	[108, 33.9%]	[15, 4.7%]
Sleeping under mosquito bed net (6)	[6, 1.9%]	[13, 4.1%]	[38, 11.9%]	[241, 75.5%]	[21, 6.6%]
Use the air- conditioning or fan (7)	[204, 63.9%]	[89, 27.9%]	[13, 4.1%]	[8, 2.5%]	[5, 1.6%]
Using insect repellent on skin (8)	[45, 14.1%]	[163, 51.1%]	[78, 24.5%]	[32, 10.0%]	[1, 0.3%]
Use an electronic bug/insect zapper (9)	[11, 3.4%]	[47, 14.7%]	[83, 26.0%]	[167, 52.4%]	[11, 3.4%]
Wear protective, long sleeved clothing (10)	[20, 6.3%]	[98, 30.7%]	[113, 35.4%]	[84, 26.3%]	[4, 1.3%]
Others; Please specify: (11)	[12, 3.8%]	[16, 5.0%]	[21, 6.6%]	[19, 6.0%]	[251, 78.7%]

Q18 What other means do you use to protect yourself from mosquito bites?

- Avoid bushes/forested/vegetation areas
- Avoid open-air activities in the night
- Lighting a candle
- Mosquito patch, repellent bands
- Use of lemongrass oil

Q19 Please rate the extent to which you agree/disagree to the following statements:

	Strongly disagree (1) [1]	Disagree (2) [2]	Neither agree nor disagree (3) [3]	Agree (4) [4]	Strongly agree (5) [5]	I don't know (6) [Missing value]
I am confident that I can prevent myself from getting Dengue/Zika (1)	[11, 3.4%]	[73, 22.9%]	[125, 39.2%]	[89, 27.9%]	[7, 2.2%]	[14, 4.4%]
I have enough information about how to protect myself and my family from Dengue/Zika (2)	[6, 1.9%]	[45, 14.1%]	[92, 28.8%]	[154, 48.3%]	[16, 5.0%]	[6, 1.9%]
I have enough information to know how to do the 5- Step Mozzie Wipeout (3)	[9, 2.8%]	[39, 12.2%]	[67, 21.0%]	[170, 53.3%]	[23, 7.2%]	[11, 3.4%]
I regularly carry out the 5-step Mozzie Wipeout to ensure that there are no mosquitoes breeding in my home (4)	[17, 5.3%]	[61, 19.1%]	[92, 28.8%]	[121, 37.9%]	[18, 5.6%]	[10, 3.1%]

Q20 Please rate the extent to which you agree/disagree to the following statements: [319]

	Strongly disagree (1) [1]	Disagree (2) [2]	Neither agree nor disagree (3) [3]	Agree (4) [4]	Strongly agree (5) [5]	I don't know (6) [Missing value]
I am able to protect myself and my family from getting Dengue/Zika just by doing the 5-step Mozzie Wipeout (1)	[9, 2.8%]	[65 20.4%]	[91 28.5%]	[120, 37.6%]	[12, 3.8%]	[22, 6.9%]
Using other recommended Dengue/Zika preventive measures will decrease my chances of getting infected with Dengue/Zika (2)	[2, 0.6%]	[10, 3.1%]	[73, 22.9%]	[193, 60.5%]	[25, 7.8%]	[16, 5.0%]
The 5-Step Mozzie Wipeout is effective to prevent mosquitoes from breeding in my house (3)	[3, 0.9%]	[7, 2.2%]	[69, 21.6%]	[191, 59.9%]	[20, 6.3%]	[29, 9.1%]

Q21 who do you think is responsible for keeping mosquitoes away? (Multiple answers possible)
Government (1) [184, 57.7%]
Town Council (2) [228, 71.5%]
Pest Control Companies (3) [131, 41.1%]
Family Members (4) [215, 67.4]
Personal Responsibility (5) [300, 94.0%]
End of Block: Attitudes, Perception & Behaviour

Start of Block: Current/Future Communication, Use of Technology, Info Dissemination

seases? (Multiple answers possible)
Family & Friends (1) [144, 45.1%]
Neighbours (2) [35, 11.0%]
NEA Officers (3) [99, 31.0%]
NEA Website (4) [135, 42.3%]
Dengue Prevention Volunteers (DPV) (5) [41, 12.9%]
Healthcare Professionals (Doctors, Nurses) (6) [59, 18.5%]
Governmental Agencies (Ministries and Statutory Boards) (7) [93, 29.2%]
Town Council (8) [80, 25.1%]
Pamphlets/Leaflets in mailbox (9) [181, 56.7%]
Grassroots/Community Events (CC/RC/NC events) (10) [61, 19.1%]
Television (11) [222, 69.6%]
Radio (12) [86, 27.0%]
Newspapers (13) [154, 48.3%]
Online News/Websites (14) [143, 44.8%]
Social Media (15) [160, 50.2%]
School (16) [76, 23.8%]
Workplace (17) [68, 21.3%]
Others, please specify: (18) [5, 1.6%]
- LSM coded modules (Life Science Modules in NUS)
- Low coded inoddies (the otience wooddies in Nos)

Q22 From which sources have you obtained information regarding mosquitoes and mosquito-borne

Posters in public spacesRoadshows
- Scientific literature
I have not received any information regarding mosquitoes/mosquito-borne diseases (19) [2 0.6%]
Q23 Do you have a smartphone?
O Yes (1) [317, 99.4%]
O No (2) [2, 0.6%]
Q24 I prefer to receive information through the following channels: (Multiple answers possible)
Notifications (from apps on phones/websites/SMS) (1) [132, 41.4%]
Online Newsletters (2) [92, 28.8%]
Print Media (Newspapers, Magazines) (3) [92, 28.8%]
Radio (4) [64, 20.1%]
Social Media (Facebook, twitter, Instagram) (5) [193, 60.5%]
Television (6) [148, 46.4%]
Word-of-mouth (7) [88, 27.6%]
Others, Please specify: (8) [5, 1.6%]
- Mailers at workplace
- Pamphlets
- Timely information on infection clusters in my vicinity

- Outdoor advertisements

Start of Block: Citizen Science / Willingness to Participate / Type of Information Wanted

Q25 Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge (observations, expertise, knowledge of an area etc) or with their own tools and resources. Having a citizen-science approach can help to narrow the gap between professional scientists and the wider public as well as empower the general public with knowledge.

Some examples of citizen science projects include getting everyday people to report sightings of migratory birds, flowering of trees. These observations are helpful for scientists in studying trends or patterns about nature, seasonal changes or even the environment, and in turn, citizens can also learn more about the environment they live in.

Q26 Do you participate in any Citizen Science project(s)?

O No (2) [296, 92.8%]

Q27 What are the Citizen Science project(s) that you participate in?

- Allergies
- CC & RC activities
- Effectiveness of intervention programs to reduce household energy consumption
- Exhibitions
- Flumob
- GalaxyZoo
- Gather ground information including mosquito breeding etc
- Mosquito prevention & awareness, bird and cat feeding education
- NPARKS BioBlitz
- NPARKS Birds, Butterflies & dragonflies observations
- NPARKS Community in Nature
- Research project on dengue virus and transmission in mosquitoes
- Sharing with recovering addicts

O Yes;	Please specify: (1) [37, 11.6%]
-	iTown@SG
-	MoBuzz
-	Breakdengue
-	Kidenga
-	OneService (by MSO)
-	myENV (by NEA)
O No	(2) [282, 88.4%]
Surveillance O Yes O No	you be interested to participate in a Citizen Science project to help with mosquito and control? (1) [42, 13.2%] (2) [101, 31.7%] (be (3) [176, 55.2%]

Q28 Do you know of any existing mobile phone applications or websites that allow you to report

mosquito nuisance or mosquito breeding?

Q30 What would motivate you to want to participate in such projects? (Multiple answers possible)		
To contribute towards mosquito surveillance and monitoring (1) [194, 60.8%]		
Gain knowledge on how to identify different mosquitoes (2) [91, 28.5%]		
Gain knowledge on various mosquito-borne diseases (3) [107, 33.5%]		
To learn how to better protect myself and my loved ones from mosquitoes and mosquito borne diseases (4) [210, 65.8%]		
Fun activities and events that surround the project (5) [112, 35.1%]		
Others, Please specify: (6) [23, 7.2%]		
- Alerts when there are outbreaks of mosquito-borne diseases in residential area		
- Excuse from work		
- If time permits; if it doesn't take too much time		
- If taken and done seriously and participants are informed of progress and outcome		
 If taken and done seriously and participants are informed of progress and outcome Monetary value e.g. vouchers for participation 		
- Monetary value e.g. vouchers for participation		
- Monetary value e.g. vouchers for participation		

Q31 What kind of information about mosquitoes would you like to receive? (Multiple answers possible)

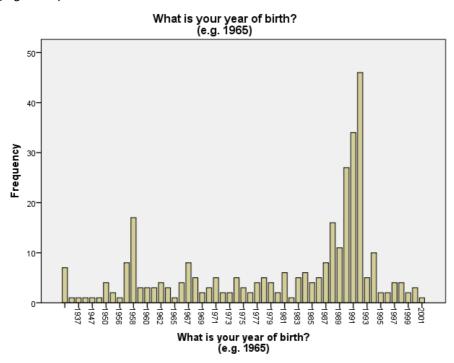
Alerts for mosquito "season" (1) [202, 63.3%]
Alerts when there are outbreaks of mosquito-borne diseases in your area (2) [232, 72.7%]
How to protect yourself and your loved ones from mosquitoes (3) [174, 54.5%
Information about mosquitoes (4) [91, 28.5%]
Information about mosquito-borne diseases (5) [143, 44.8%]
I am not interested in information about mosquitoes (6) [18, 5.6%]

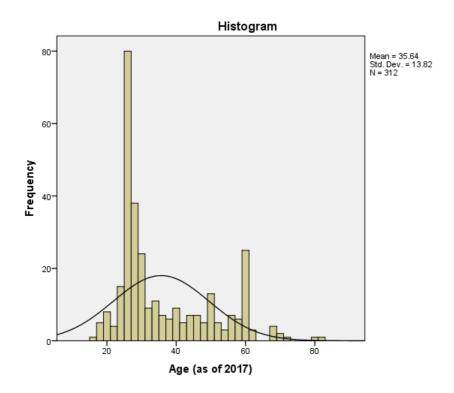
I am not interested in information about mosquito-borne diseases (7) [7, 2.2%]

End of Block: Citizen Science / Willingness to Participate / Type of Information Wanted

Start of Block: Demographics

Q32 What is your year of birth? (e.g. 1965)





Q33 Gender:

- Female (1) [188, 58.9%]
- O Male (2) [131, 41.1%]

Q34 How long have you lived in Singapore?

- O All my life (1) [281, 88.1%]
- 1-2 years (2) [2, 0.6%]
- 3-5 years (3) [3, 0.9%]
- Others, please specify the number of years: (4) [33, 10.3%]
 - 7/9/10/11/15/16/17/20/22/23/25/27/30/46/50/56/60/61

Q35 Highest educational qualification obtained:		
O No formal education (1) [2, 0.6%]		
O PSLE (2) [1, 0.3%]		
O GCE O/N Levels (3) [33, 10.3%]		
○ GCE A Levels / International Baccalaureate (IB) (4) [18, 5.6%]		
O Higher Nitec and Nitec (5) [2, 0.6%]		
O Polytechnic Diploma (6) [41, 12.9%]		
O Bachelor's Degree (7) [187, 58.6%]		
O Master's Degree / Postgraduate (8) [28, 8.8%]		
O Doctorate (9) [4, 1.3%]		
Others (10) [3, 0.9%]		
Q36 Occupation:		
O Student (1) [37, 11.6%]		
O Housewife/Househusband (2) [7, 2.2%]		
O Working Professional (3) [244, 76.5%]		
O Unemployed (4) [9, 2.8%]		
O Retired (5) [21, 6.6%]		
End of Block: Demographics		