

Study on the Weather Effects on Dengue and Dengue Surveillance System in Fiji

by

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Global Health Program
Duke Kunshan University and Duke University

Date: April 5th, 2017

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Chris Woods

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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ABSTRACT

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Abstract

Background: Dengue is one of the most common vector transmitted diseases in the world and it has become a public health problem in many countries including Fiji. Efficient methods need to be taken for dengue prevention and control in Fiji. Disease surveillance is one of the most effective way for dengue prevention and idea of using weather parameters to estimate dengue cases as one part of dengue surveillance has been studied by different researchers worldwide. The study aimed to estimate the relationship between weather variables including rainfall, temperature and humidity and to identify problems existed in current surveillance system in Fiji. Methods: Both quantitative and qualitative methods were used in the study. In the quantitative study, disease data of dengue cases collected by Fiji National Notifiable Disease Surveillance System from Jan 2011 to Dec 2014 and weather data collected by meteorological station in Laucala Bay, Suva from Jan 2011 to Dec 2014 were provided by Fiji Ministry of Health. Disease data were divided into two parts, years with sporadic cases (Jan2011-Oct2013) and years with dengue outbreak (Nov2013-Dec2014), and negative binominal regression was conducted to estimate the association between weather variables including rainfall, maximum temperature, minimum temperature and relative humidity. In the qualitative study, in-depth interviews were conducted with health workers and dengue patients in Suva and evaluations of current surveillance system and problems being noticed in the surveillance system were discussed. Results: Statistically significant positive

associations between weather variables including weekly cumulative rainfall and weekly average relative humidity and dengue cases were identified in years with sporadic cases. In years with dengue outbreak, weekly average maximum temperature and relative humidity were also found to be significantly positively associated with dengue cases. Average minimum temperature per week was found to be significantly negatively associated with dengue cases. Problems of timeliness, accuracy and completeness in dengue case report process were identified and inadequate public health awareness of health workers was also raised in the interviews. Conclusions: Weather variables including rainfall, temperature and humidity showed significant effects on variations of dengue cases. The significant associations between weather variables and dengue cases may establish the foundation of developing a climate-based early warning system for dengue in Fiji. Problems in the current surveillance system for dengue have been identified including lack of timeliness and compromised quality in the case reporting process. Web-based disease reporting system and standardized reporting procedures may be useful in improving the surveillance system. A more efficient disease surveillance system can be developed combining the effects of weather variations on the number of dengue cases and routine surveillance together.

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1. Introduction

Dengue is one of the most common vector transmitted diseases in the world and it has become a serious public health problem in many countries (WHO, 2012; Gibbons & Vaughn, 2002). According to an estimate conducted by Bhatt et al (2013), around 390 million (95% credible interval 284–528 million) dengue infections happen worldwide every year and 96 million (95% CI 67-136 million) of them show apparent clinical manifestations. With no licensed vaccine and specific treatment for dengue currently available (WHO, 2009; Tatem et al, 2006) and with huge numbers of people (2.5 billion) living under the risk of being infected (WHO, 2012), efficient methods need to be employed for dengue prevention and control in those regions where dengue is of high prevalence and incidence.

1.1 Disease burden of dengue in Fiji

According to an infectious disease report by the World Health Organization (WHO), member countries in the WHO Western Pacific Region experienced more dengue cases and a higher frequency of dengue epidemics than other regions (WHO, 2011). Since 2013, a high level of dengue activity has been observed in Fiji and over 28,000 suspected cases and 12 confirmed deaths were reported from November 2013 to November 2014 (WHO, 2014; MoH-Fiji, 2014). Both local government and international institutions were have become increasingly concerned about this dengue outbreak (WHO, 2014). This particular dengue outbreak was caused by dengue virus serotype 3

(DENV-3) which has reemerged in Fiji after 20 years of no cases having been reported (MoH-Fiji, 2014; WHO, 2014). The absence of serotype 3 resulted in immunological vulnerability to this serotype, which could have led to increased incidence and severity of the outbreak (Morens et al. 2004).

1.2 Current surveillance system for dengue in Fiji

Disease surveillance is critically important in preventing a dengue outbreak and in minimizing harms caused by an outbreak should one occur. Both epidemiological and entomological surveillance, as well as weekly case reporting were listed among the best practices for dengue prevention and control in the Americas (Lloyd, 2003). According to the International Health Regulations (IHR) adopted by all of the World Health Organization (WHO) countries including Fiji, infectious diseases such as dengue need to be detected, assessed and reported in a timely manner (WHO, 2008). In Fiji, dengue has been one of the prioritized surveilled communicable diseases which required to immediate and urgent notification by Medical Officers and Laboratories when a case was identified (MoH-Fiji, 2010).

Currently, there are two surveillance systems for communicable diseases in Fiji. The Fiji National Notifiable Disease Surveillance System (NNDSS) and The Fiji Syndrome Surveillance System (FSSS) are both conducting dengue surveillance in Fiji (MoH-Fiji, 2010; MoH-Fiji, 2015)

1.2.1 Fiji National Notifiable Diseases Surveillance System (NNDSS)

According to the Fiji Ministry of Health (2010), dengue was one of the important infectious diseases monitored by NNDSS. This system maintains a public health process for the collection, analysis and reporting of data about dengue cases. In Fiji, health workers using the NNDSS were directed to report suspected and confirmed cases from the district level to the Permanent Secretary for Health. Suspected dengue patients identified by physicians in local health centers were reported to subdivision medical officers, divisional medical officers and the Fiji Center for Communicable Disease Control (FCCDC), successively. For routine conditions, health workers were required to report dengue cases on a weekly basis. When increased numbers of suspected dengue cases were observed, urgent reporting by immediate telephone communication to the higher levels of the health sectors was required. Blood samples collected by physicians and nurses in local health centers were sent to laboratories for confirmation and also sent to the lab in FCCDC to identify the serotype of dengue. Health inspectors also investigated the travel histories of patients, investigating possible routes of infection of new dengue cases. Analysis of the epidemiological situation was then conducted by FCCDC and reported to the Deputy Secretary of Public Health and The Permanent Secretary for Health to determine whether an outbreak of dengue has happened or not. Environmental and behavioral interventions were conducted afterwards.

1.2.2 Fiji Syndrome Surveillance System (FSSS)

The Fiji Syndrome Surveillance System is part of the greater Pacific Syndrome Surveillance System that has been promoted and adopted in 20 Pacific island countries and territories, including Fiji, since 2010 (Kool et al., 2012). Sentinel sites in Fiji were chosen to participate in this system in order to avoid placing the extra burden of data collection on the public health system (MoH-Fiji, 2015; Kool et al, 2012). Health workers using the FSSS in the sentinel sites were required to report four basic syndromes every week to the FCCDC, including acute fever and rash, prolonged fever, influenza-like illness, and diarrhea. After the dengue outbreak in Fiji in 2013 and 2014, dengue-like illness and four other basic syndromes were required to be reported in this system as well as other four basic syndromes (MoH-Fiji, 2015). Analysis of surveillance data was then undertaken and reported back to those sentinel sites, as well as to the larger Pacific Syndrome Surveillance System. Early detection and early interventions of disease epidemics should be conducted using FSSS.

1.3 Climate-based Early Warning System

Early warning systems (EWS), provide timely information to people exposed to catastrophic events, such as dengue outbreaks, and allow health care sectors to prepare in order to reduce the risk of suffering from these events. Some researchers suggest that EWS are important for dengue surveillance (Lowe et al, 2013). As a vector-transmitted disease, dengue is highly associated with the patterns of its vector, a mosquito called

Aedes aegypti. The temperature, wind speed, rain fall and humidity all influence the mosquito pattern, and these conditions have been found to possibly predict epidemics of dengue in Fiji and other Pacific countries (Cheong et al., 2013; Stewart-Ibarra & Lowe, 2013; Sang et al., 2014). As a Pacific island country, Fiji is one of the most vulnerable countries to climate changes and climate-sensitive diseases (Ebi et al., 2006). Promising benefits of a climate-based early warning system for infectious diseases, including dengue, were identified in studies conducted in Brazil and Ecuador (Lowe et al., 2013; Rogers and Tsirkunov, 2011). Similarly, studies conducted in China and Malaysia also reflected a significant association between the number of dengue cases and weather data, including temperature, vapor pressure and minimum humidity (Sang et al., 2014; Cheong et al., 2013). For Fiji, a study based on disease data and climate data from 2003 to 2007 has shown that the incidence of dengue increased significantly after extreme weather events, such as the tropical cyclones, and incidence of dengue has also been associated with climate variability (Tabua, Kubuabola & Rafai, 2013). These studies have been foundational in providing support for the implementation of a climate-based early warning system for better prevention and control of dengue. The implementation of a climate-based early warning system can be an effective way to prevent and control dengue outbreak in advance.

1.4 Concerns of current surveillance and potentials of developing Early Warning System

Although Fiji had two surveillance systems monitoring dengue cases, prevention and control of the disease were not successful and effective implementation of the early warning system was also limited (Moceituba & Tsang, 2015). Researchers have found that several problems in the current surveillance system impeded the effective delivery of EWS for dengue fever. For example, compromised quality of reported data and the poor timeliness of report submission in Fiji (McIver et al, 2012). Inaccuracy and incompleteness of case reports may also have impeded timely interventions (Moceituba & Tsang, 2015). In addition, a case study conducted by Morrow & Bowen (2014) argued that national policies on climate change and public health were always indirectly or minor related to health. Health impacts related to climate change were not emphasized at the policymaking levels. The completeness, timeliness and accuracy of data collected by current Fiji surveillance system might not be sufficient enough to support effective dengue prevention and to support the effective implementation of early warning system (Paterson et al., 2012; Roth et al., 2014; McIver et al., 2012).

Currently, the specific problems in the current surveillance systems of Fiji that are impeding the effective prevention and control of dengue are still not sufficiently identified. A clear description of current surveillance procedures and identification of the problems that are impeding the effective prevention and control of dengue is needed.

The examination of potential solutions can be helpful to enhance the surveillance system for dengue and reduce harms to people exposed to the risk of dengue fever in advance.

2. Objectives

This study aimed at describing and analyzing public health activities focusing on communicable diseases surveillance especially on surveillance for dengue.

AIM I: Based on the weather data collected in Suva subdivision and disease cases reported there, to examine the association between weather variations and incidence dengue cases in Suva subdivision.

AIM II: Through interviewing the health workers working on dengue surveillance and previous dengue patients, to identify problems that exist in the current dengue surveillance system and to raise recommendations to improve future dengue disease surveillance and prevention in Fiji.

3. Methods

This study was divided into two parts. The first part analyzed the relationship between weather fluctuations and variations of dengue cases using a time-series negative binominal regression model. The second part of the study analyzed the surveillance system in Suva, Fiji using in-depth interviews.

3.1 Data analysis on the relationship between weather variations and dengue incidents in Suva, Fiji

3.1.1 Weather data

Original weather data from Jan 1st, 2011 to Jul 31st, 2015 were provided by the Fiji Ministry of Health. Weather data were monitored and collected at the meteorological station in Laucala Bay, Suva. Original weather data, including daily rainfall, maximum temperature, minimum temperature and relative humidity, was processed by Stata/SE 12. In order to be conformed with the timeline of disease data, weather data collected after Jan 1st, 2015 was dropped from the dataset. Extreme weather records which were unlikely to exist in Fiji, Suva, including temperature higher than 100°C and lower than 5°C were replaced with missing values. Other variables including weekly cumulative rainfall, average maximum temperature per week, average minimum temperature per week and weekly average relative humidity were generated based on original data. Considering the influence of seasonal change of weather in Fiji, the wet season

(November to April) and dry season (May to October) were also marked by a categorical season variable.

3.1.2 Dengue data

Original records of dengue cases were obtained from the Fiji National Notifiable Diseases Surveillance System (NNDSS) and the Fiji National Syndrome Surveillance System (NSSS). Dengue cases identified from Jan 2011 to Dec 2014 in Suva sub-division were reported by public health centers, divisional hospitals, private hospitals and other health facilities in Suva. Since dengue like illnesses were reported after the dengue outbreak in 2014, no dengue-like illness was reported from 2011 to 2013 (MoH-Fiji, 2015). Because of the absence of syndrome based surveillance from 2011 to 2013, data from syndrome based surveillance system was dropped from the analysis. All of the cases were identified based on criteria of suspected and diagnosed dengue in the *Communicable Disease Surveillance Outbreak Response Guideline* (MoH-Fiji, 2010). Original case data included diagnosed dengue cases from 2011 to 2014 and suspected cases during the dengue outbreak in 2013 and 2014. For the consistency of the data, only confirmed cases recorded by NNDSS were included for the analysis. Cases data were cleaned using Stata/SE 12 by the researcher. In order to maintain confidentiality, all of the patients' names were transformed into a unique case ID. Other identifiable information of the patients was removed from the data, including detailed addresses.

Six age groups were generated, which were 0-4, 5-9, 10-14, 15-39, 40-59, 60+, respectively, and dengue cases were classified into their corresponding group respectively. Based on the ethnicity of each patient, cases were also classified into three ethnicity groups including Fijian of Indian descent, iTaukei and Fijian of other descent. According to the location and character of reporting facilities, the reporting facilities were classified into 9 categories: six health centers (Lami Health Center, Makoi Health Center, Nuffield Health Center, Raiwaqa Health Center, Samabula Health Center, Valelevu Health Center) in Suva-subdivision, one divisional hospital (Colonial War Memorial Hospital), one private hospital (Suva Private Hospital) and other health facilities. Patients were also categorized into two groups based on the reporting facilities categories; one group reported by hospitals (CWM and Suva Private Hospital) and the other group reported by health centers. Cleaned case information included age group, gender, ethnicity, date of notification and report facilities.

3.1.3 Statistical model

Variable 'y' was generated to be the number of cases notified on the same day with the identical gender, age group, ethnicity and notified area. Disease data were transformed into time series panel data based on the categories of age group (6 categories+1 category of missing values), ethnicity (3 categories+1 category of missing values), gender (2 categories+1 category of missing values) and notified areas of

dengue cases (9 categories). Panel data were merged with weather data based on the temporal variable. Since the dengue outbreak started from November 2013, the data set was divided into two parts: Jan 01, 2011-Oct 31, 2013 (first part) and Nov 01, 2013-Dec 31, 2014 (second part), in order to avoid the influence of different epidemic degrees. Both parts of the data set were analyzed using the same statistical method.

Time series negative binominal regression was used to analyze the relationship between dengue cases and weather variations. For each part of the data set, the data was summarized by week first. The time series variable was declared by weekly and the number of dengue cases per week was generated. Negative binominal regression was conducted between the number of weekly dengue cases and each weather variable respectively including weekly cumulative rainfall, average maximum temperature per week, average minimum temperature per week and weekly average relative humidity. Each regression was conducted with 20 time lags (week) to determine the time period during which each weather variable had the greatest impact on number of dengue cases. Scatter plots of the coefficients which were calculated by each regression model were graphed using Microsoft Excel 2007 to identify the most relevant time lags. Based on previous calculations, another negative binominal regression model clustered by week was constructed to examine the relationship between dengue cases and all the weather variables with time lags. Demographic variables were also included in this model to identify and allow for other influencing factors.

3.2 In-depth interview of the surveillance system in Suva, Fiji

3.2.1 Study Setting

The study was conducted in the Suva sub-division, Fiji with the support of the World Health Organization Western Pacific Regional Office and the Fiji Ministry of Health and Medical Services. Suva, the capital city of Fiji, belongs to the Suva Subdivision, Central Division. One divisional hospital, one private hospital, seven health centers and one nursing station are located in this sub-division. Both Fiji National Notifiable Diseases Surveillance System and Fiji Syndrome Surveillance System were conducted in Suva and this study was conducted in health sectors related with dengue surveillance including Fiji Centre for Communicable Disease Control (FCCDC), divisional hospital, sub-divisional medical office and health centers.

3.2.2 Participants

Both health workers working in related health sectors and previous dengue patients (both confirmed and suspected patients) were recruited in this study. Health workers from FCCDC, divisional hospital and sub-divisional medical office were recruited based on their work responsibilities and experience in dengue surveillance and prevention. Health centers were selected randomly first and health workers who were responsible for dengue surveillance and prevention were recruited from these randomly selected health centers based on their work experience. Patients who were not less than

18 years old and had diagnosed or suspected dengue during the 2013 dengue outbreak in Fiji were recruited using the convenience sampling method. All of the participants, both health workers and previous dengue patients, were asked about their willingness to participate in the study before the interview and details of the study were fully explained.

3.2.3 Procedures

In-depth interviews were conducted with each participant individually by researchers in a private and comfortable environment. For health workers, interviews were conducted in their personal offices. For patients, interviews were conducted in their houses or other private environment. The only people present during the interviews were the researchers and interviewees. Interview guidelines were designed by researchers for different groups of health workers and patients respectively. Each interview with health workers lasted around 45 minutes and each interview with patients lasted about 30 minutes. Small gifts (around \$5) were given to participants as compensation for their time and efforts. All of the interviews were recorded with the permission of the participants. Records were transcribed into Word documents after the interviews by the researcher afterwards. Anonymity was assured by deleting the personal characteristics of participants after the transcription.

This study was approved by the Institutional Review Board of Duke University. Signed informed consents were obtained from all the interviewees, including both health workers and patients.

3.2.4 Measures

Interview guidelines for health workers and patients were designed separately. Questions for health workers covered: 1) procedures of identifying dengue patients; 2) procedures of reporting dengue cases; 3) evaluations of the surveillance system such as quality of collected information, timeliness of reporting, sufficiency of resources; 4) perceived and potential problems in the surveillance procedures; 5) suggestions to those resolve problems. Questions for dengue patients covered: 1) time and place patients were identified as suspected or diagnosed dengue patients; 2) procedures of being identified as dengue patients; 3) awareness and knowledge of methods of dengue prevention; 4) information and intervention received from communities for dengue control and prevention; 5) evaluation of public health interventions received from health centers or public health staff.

3.2.5 Analyses

Systematic Text Condensation was used to analyze the transcribed interview text. The steps of the analysis were guided by principles and procedures developed by Malterud (2012). The whole interview transcription was first read to get a general impression of the interviews. Preliminary themes were identified during the overview

of data. The second step of analysis was to identify and code meaning units related with previously identified themes such as timeliness of reporting. Coded meaning units were condensed into groups and the original transcription was then decontextualized into thematically code groups which revealed concerns about the dengue surveillance system. Finally, synthesizing was conducted to provide descriptions and concepts of the interviewees' opinions on dengue surveillance and prevention in Suva, Fiji.

4. Results

4.1 The relationship between weather variables and dengue incidence in Suva, Fiji

4.1.1 Description of Notified Dengue Cases in Suva from 2011 to 2014

Since the dengue outbreak happened in Fiji in 2013 and 2014, the number of disease cases increased significantly between 2013 and 2014. The temporal distribution of notified dengue cases in Suva from 2011 to 2014 is shown in Figure 1 and Figure 2. From 2011 to 2014, 1299 dengue cases were identified by the NDSSS. Tables 1, 2, 3, 4 show the number of cases in each year from 2011 to 2014 by categories of gender, ethnicity, age group and notified areas of the case respectively. Among all of the cases identified from 2011 to 2014, 54.5% of the cases were males and 43.4% were females. The Suva Private Hospital reported the largest proportion of dengue cases from 2011 to 2014, followed by the Colonial War Memorial Hospital (CWM Hospital). More than half of all notified cases (57.5%) in NNDSS were notified by Suva Private Hospital and CWM hospital. Among all of the cases recorded in NNDSS, only 49.0% of the cases had detailed addresses recorded. Suva Private Hospital had the highest ratio of reported cases with detailed addresses (84.6% of all cases reported by Suva Private Hospital).

Figure 1: Weekly Dengue Cases from Jan 2011 to Oct 2013

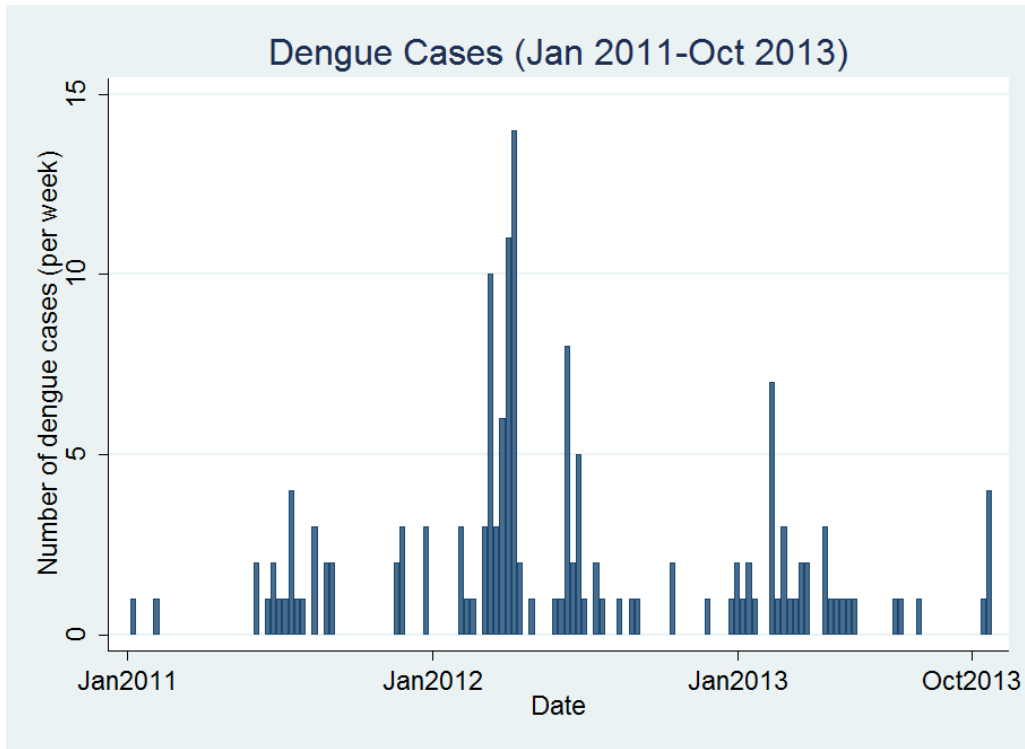


Figure 2: Weekly Dengue Cases from Nov 2013 to Dec 2014 (note change of scale)

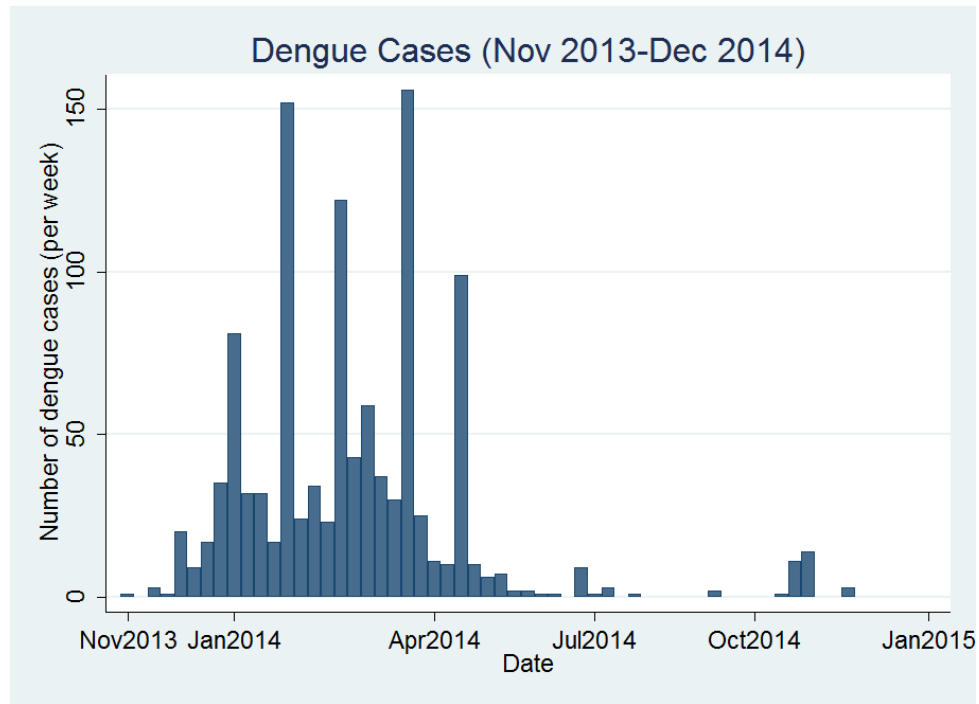


Table 1: Number of Dengue Cases by Gender (2011-2014)

	2011	2012	2013	2014	Total
Male	17	57	121	513	708(54.5%)
Female	13	28	81	442	564(43.4%)
Unknown	0	0	2	25	27(2.1%)
Total	30	85	204	980	1299

Table 2: Number of Dengue Cases by Ethnicity (2011-2014)

	2011	2012	2013	2014	Total
Fijian of Indian Descent	16	44	114	515	689(53.0%)
iTaukei	10	25	57	309	401(20.9%)
Others	4	16	27	138	185(14.2%)
Unknown	0	0	6	18	24(1.8%)
Total	30	85	204	980	1299

Table 3: Number of Dengue Cases by Age Group (2011-2014)

	2011	2012	2013	2014	Total
0-4	0	2	1	17	20(1.54%)
5-9	3	4	7	35	49(3.77%)
10-14	2	4	22	48	76(5.85%)
15-39	15	35	72	346	468(36.03%)
40-59	1	12	22	155	190(14.63%)
60+	0	2	14	30	46(3.54%)
Unknown	9	26	66	349	450(34.64%)
Total	30	85	204	980	1299

Table 4: Number of Dengue Cases by Notified Areas (2011-2014)

	2011	2012	2013	2014	Total
CWM Hospital	21	10	28	130	189(14.5%)
Suva Private Hospital	6	38	62	452	558(43.0%)
Lami Health Center	0	0	0	39	39(3.0%)
Makoi Health Center	0	1	5	60	66(5.1%)
Nuffield Health Center	0	25	18	40	83(6.4%)
Raiwaqa Health Center	0	0	15	41	56(4.3%)
Samaula Health Center	0	0	41	88	129(9.9%)
Valelevu Health Center	3	10	33	70	116(8.9%)
Others	0	1	2	60	63(4.8%)
Total	30	85	204	980	1299

4.1.2 Temporal Variation in Weather Parameters in Suva from 2011 to 2014

Average relative humidity varied between years and was significantly higher in 2011 and 2012 than in 2013 and 2014. Although, there is no significant difference of rainfall from 2011 to 2014, seasonal variation of rainfall was observed with the monthly rainfall being significantly higher in the Fijian wet season (November to April) than in the Fijian dry season (May to October). Humidity in years with sporadic dengue cases (Jan2011-Oct2013) was significantly higher than years with dengue outbreak (Nov2013-Dec2014) and average minimum temperature per week was also significantly higher in years with sporadic dengue cases. No significant difference of average maximum temperature per week among those years was observed. Figure 3, 4, 5 show the

temporal variation of rainfall, average temperature and relative humidity in each month from 2011 to 2014.

Figure 3: Monthly Rainfall (2011-2014)

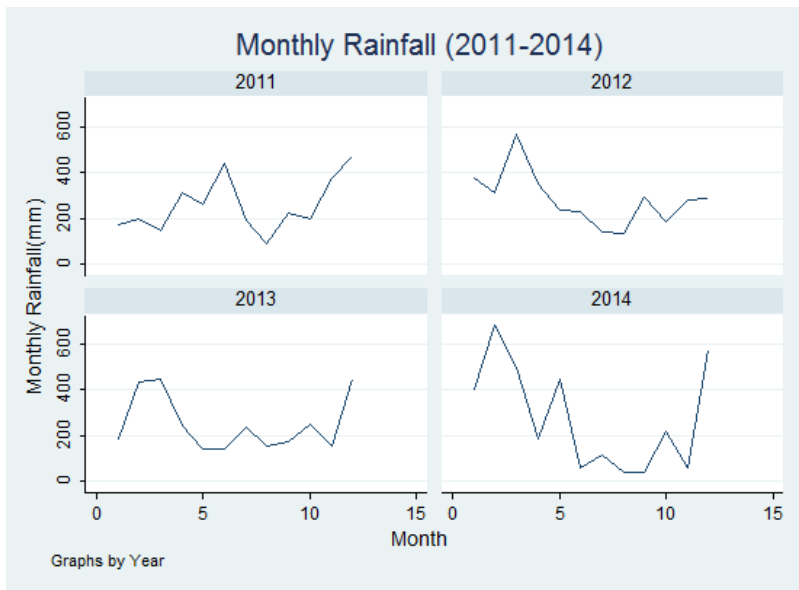


Figure 4: Average Temperature per month (2011-2014)

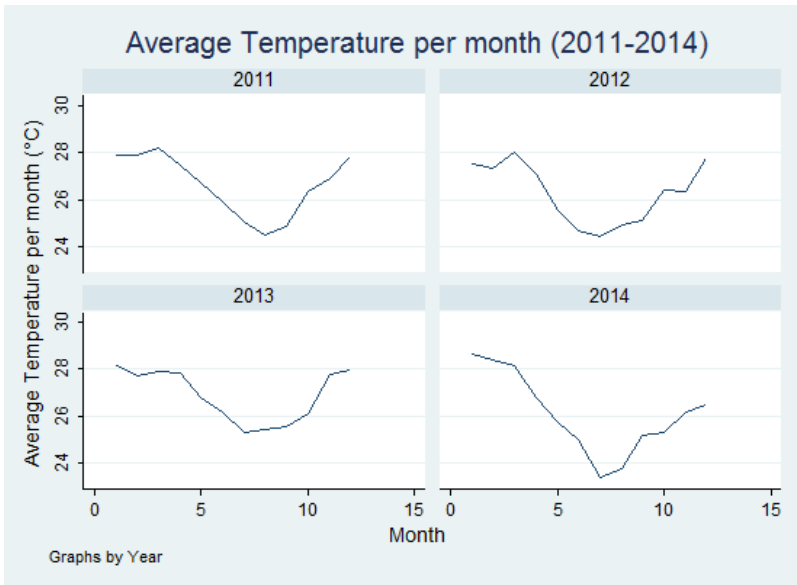
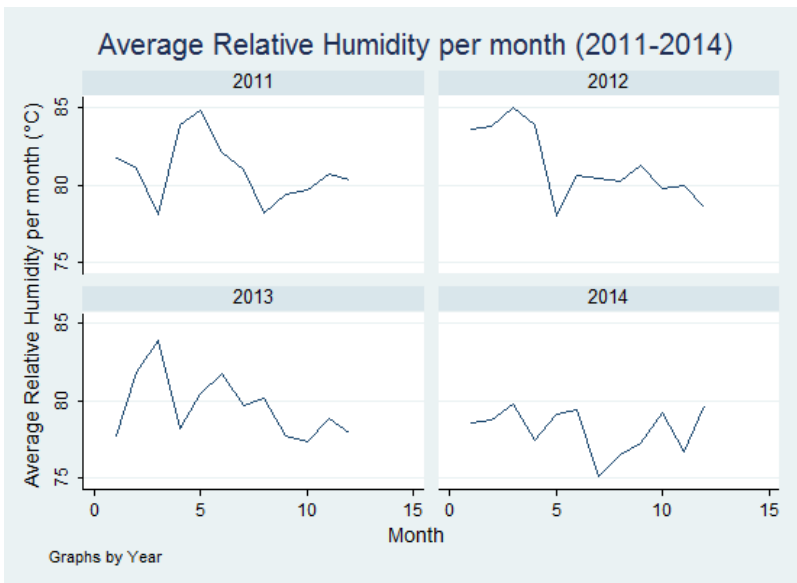


Figure 5: Average Relative Humidity per month (2011-2014)



4.1.3 Relationship between weather variables and dengue cases

For each weather variable, relevant time lags were identified by a two way scatter plot of coefficients calculated in separate regression models (Appendix A and B). Additional time lag variables were generated based on those relevant time periods being identified for each weather variable. During years with sporadic dengue cases, weekly cumulative rainfall around one week and three months ahead of the time cases were reported were found to be more relevant with weekly dengue cases. Different time lags were identified to be more relevant with weekly dengue cases for other weather variables, around three months for average minimum temperature per week and weekly relative humidity and around four months for average maximum temperature per week. During the years with outbreak dengue epidemic, a time lag around one month was identified to be more relevant for weekly cumulative rainfall and a time lag around two months was chosen for average maximum temperature per week, average minimum temperature per week and weekly average relative humidity. Table 5 shows the chosen time lags for each weather variable.

Table 5: Chosen time period for each weather variable

<i>Weather Variable</i>	<i>Chosen Time period-sporadic</i>	<i>Chosen Time Period-outbreak</i>
<i>Rainfall</i>	0-1 week	3-6 week
	10-14 week	
<i>Maximum Temperature</i>	15-18 week	5-8 week
<i>Minimum Temperature</i>	11-14 week	6-9 week
<i>Relative Humidity</i>	10-12 week	2-4 week
		9-10 week

Two regression models were generated for two different epidemic degrees. During years with sporadic dengue cases (Jan2011-Oct2013), weekly cumulative rainfall with time lags of 0-1 week and 10-14 week and weekly average relative humidity with a time lag of 10-12 week showed to be significantly positively associated with weekly dengue cases. Average maximum temperature per week and average minimum temperature per week did not show significant association with weekly dengue cases. Different results were found during years with dengue outbreak (Nov2013-Dec2014). No statistically significant association was identified between weekly cumulative rainfall and weekly dengue cases. Different from the results during years with sporadic cases, average maximum temperature per week with time lag of 5-8 week and weekly average relative humidity with time lags of 2-4 week and 9-10 week showed significant positive associations with weekly dengue cases. Average minimum temperature per week with

a time lag of 6-9 week also showed significant negative association with weekly dengue cases. Table 6 and Table 7 showed results in two regression models.

Table 6: Relationship between weather variables and weekly dengue cases (Jan 2011 to Oct 2013).

Weather Variables	IRR(95%CI)	p-value
Rainfall (0-1 week) (per 100mm)	3.04(1.87, 4.95)	<0.01
Rainfall (10-14 week) (per 100mm)	3.32(1.09, 10.17)	0.04
Maximum Temperature (15-18 week) (° C)	0.89(0.67, 1.18)	0.42
Minimum Temperature (11-14 week)(° C)	1.41(0.88, 2.25)	0.15
Relative humidity (10-12 week)(%)	1.13(1.02, 1.25)	0.02
Pseudo R squared=0.14		<0.01

Table 7: Relationship between weather variables and weekly dengue cases (Nov 2013 to Dec 2014)

Weather Variables	IRR(95%CI)	p-value
Rainfall (3-6 week) (per 100mm)	0.53(0.19, 1.49)	0.23
Maximum Temperature (5-8 week) (° C)	9.38(3.59, 24.48)	<0.01
Minimum Temperature (6-9 week)(° C)	0.25(0.09, 0.73)	0.01
Relative humidity (2-4 week)(%)	1.35(1.09, 1.68)	<0.01
Relative humidity (9-10 week)(%)	1.08(0.94, 1.24)	0.27
Pseudo R squared=0.17		<0.01

4.2 In-depth interview of the surveillance system in Suva, Fiji

Fourteen in-depth interviews were conducted in total with nine health workers and five previous dengue patients. Among these nine health workers, two of them were health workers from the FCCDC, three of them worked in divisional hospitals, two of them were sub-division officers and two of them worked in local health centers. Among the five patients, four were females and one was male.

4.2.1 Perspectives of health workers on dengue surveillance in Fiji

Several aspects of concerns of the surveillance systems for dengue have been identified by health workers.

4.2.1.1 Timeliness of dengue surveillance

Timeliness in the surveillance system was of concern for health workers. Dengue cases were reported using a paper-based system and report forms were delivered to the higher levels of the health sectors irregularly by health workers. Health workers expressed that there was no fixed date for them to report disease cases. One sub-divisional medical officer (female) said, *“the delivery of report forms highly relied on the schedule of the availability of vehicles, which came irregularly to those health centers to pick up dengue line list and blood samples. If health workers in those health centers got lucky, they could have the vehicle deliver their blood samples and report forms in 24 hours. However, this usually took more time.”* In the routine surveillance, health workers would report dengue-like illnesses weekly. Line lists of dengue cases were reported being sent at irregular dates

every week to sub-divisional medical offices, divisional medical offices or to the FCCDC. It was noted that health centers and hospitals with good facilities would be able to report in a timely manner. However, in many remote areas where internet or other facilities were not widely available, reporting dengue cases would take more time.

Beside the punctuality of reporting dengue cases, both medical officers and health workers in health centers expressed concerns about the delay of laboratory confirmations of suspected dengue cases. One of the health workers in the divisional hospital said, *“Since the patients might already left health centers or hospitals when the diagnosis came out, it would take some time to track them and deliver some necessary information to them”*.

4.2.1.2 Accuracy, completeness and consistency of collected information

Most of the interviewed health workers expressed concerns about accuracy, completeness and consistency of reported information of dengue cases. Since many reporting forms were handwritten by physicians or nurses, health workers in labs and surveillance units described the challenges they had experienced in identifying information in those forms. Medical officers expressed difficulties in investigating dengue cases since detailed addresses of patients were rarely included in the reported information. *“Only general areas could be inspected by public health staff due to the lack of detailed addresses and contact numbers of patients”* expressed by one medical officer (female). Health workers in the divisional hospital also expressed difficulties tracking

patients after they were identified as suspected dengue patients for the first time because of the incompleteness of information collected, especially for those patients who came to the emergency departments.

Different formats of health investigation forms and disease line listing forms were identified in different health centers and sub-divisional medical offices. Health workers in the FCCDC reflected with the same basic structure, variations existed in different report forms. It would take time and efforts to clean the data being reported.

4.2.1.3 Sufficiency of human and material resources

Human resources were reported to be in deficiency in health sectors. Physicians and nurses from health centers described working with double responsibilities, both taking care of patients and handling public health work. Health workers in FCCDC also stated that due to the shortage of health workers in the public health sectors, from health centers to FCCDC, and the heavy burden of work, challenges had been put to surveillance work for communicable diseases.

In addition to insufficiency of human resources, the infrastructure for the surveillance system in some health centers was reported to be deficient. Transportation for blood samples and lab kits for dengue virus were both in short supply, resulting in the delayed delivery of blood samples and diagnosis of diseases, according to the health workers from FCCDC and the sub-divisional medical offices. Interviewees also reported

that internet service was not available in some health centers and quick lab confirmation of suspected dengue cases was available in hospitals, but not in all the health centers.

4.2.1.4 Public health awareness of health workers

Health workers from FCCDC, divisional hospital, sub-divisional medical offices and health centers all expressed the need for more training on public health awareness and interventions for community health workers. *‘Some of them do not know much on public health interventions and the importance of conducting public health interventions’* according to a staff (female) working in the health center.

4.2.2 Perspectives of patients on dengue surveillance in Fiji

Although the patients did not participate in the dengue surveillance systems, as users of public health systems, patients also reflected concerns about the dengue surveillance systems from a different perspective than that of the health workers.

4.2.2.1 Awareness and knowledge of dengue prevention methods

All of the five interviewed patients expressed awareness of the dengue outbreak from 2013 to 2014. However, none of them had linked the outbreak with their own syndromes when they get infected. Dengue syndromes were unclear to those patients. One patient (female, 60s) said, *“I rested for two days before my priest asked me to see the doctor. I thought it was a simple cold and I could had recovered by myself.”* All of the patients stated that they had received basic information on the disease vector, transmission routes and prevention methods from the media and from their physicians. However,

they also expressed a lack of understanding of details about dengue transmission and prevention modes, such as the reason why they should clean their water tanks.

4.2.2.2 Acceptance and Compliance of public health interventions

Patients described having received information about some interventions and suggestions from their physicians and health workers. However, the frequency of disease interventions was not high. Few interventions were reported being conducted in the communities and were usually conducted in monotonous form. In addition, compliance of public health interventions was reported to be low.

“I got dengue three times last year, a severe one for the first time and two minor ones afterwards.

The doctors told me to clean my house but I was too lazy to do that.” – Patient (male, 40s)

Two of those patients reported having their houses sprayed and cleaned by health workers and all of them reported that little of the work of cleaning mosquito breeding sites and spraying their houses had been done by themselves. Bed nets were also rarely seen in use in the residences' houses at the time of interviews.

5. Discussion

5.1 Relationship between weather parameters and dengue cases

One aim of this study was to identify the association between weather variables and dengue cases. This includes estimating the lag time of each weather parameter. As was shown in the results above, weekly cumulative rainfall, weekly average maximum temperature and weekly average humidity were found to be positively associated with dengue cases at different time lags. Weekly cumulative rainfall was reported to be most significantly associated with weekly dengue cases at a time lag of around three months (10-14 weeks). Previous studies also reported positive effect of increased rainfall on dengue cases at different time lags (Hurtado-Díaz et al, 2007; Gomes et al, 2012). Increased rainfall could result in more breeding sites for dengue vectors and would benefit the development of mosquito larva (Wardekker et al, 2012). Empty water containers outdoors including parks and open-air restaurants can be filled during rainy season creating more breeding habitats for dengue vectors (Lowe et al, 2011). Flying range and activity of dengue vectors could be influenced by rainfall and more vectors would tend to seek shelters during rainy days (Wardekker et al, 2012).

Weekly average maximum temperature was also found to be significantly positively associated with dengue cases at a time lag of around two month (5-8 week), which was consistent with studies conducted in Guangzhou, Taiwan and Malaysia (Liu et al, 2009; Wu, 2007; Cheong et al, 2009). Studies found that temperature can influence

the development of dengue virus in its vector, *Aedes albopictus*, and with the increase of temperature extrinsic incubation period (EIP) would decrease correspondingly (Watts, 1987; Rohani, 2009). In addition, the development time of dengue vectors from larva to adult mosquito can also be affected by temperature (Farjana, Tuno & Higa, 2012). The decreased development time with increasing temperature could result in more dengue vectors. However, a higher risk of getting infected in cold weather also exists. A different flying pattern of dengue vectors was observed that flying range of dengue vectors is larger in 15° C than in 27° C, which leads to higher risk of infection of dengue virus (Rowley & Graham, 1968). This may explain the negative association between average minimal temperature per week and dengue cases.

Relative humidity showed significantly positive association in both parts of the epidemic years at different time lags, which was also shown in Lu et al's study (2009). Change of relative humidity could be a result of rainfall and study showed that increased humidity is associated with enhanced flying activities of dengue vectors, which could lead to higher risk of infection of dengue virus (Wardekker et al, 2012).

Analysis results showed two different association models for the two parts of the whole study, part I-years with sporadic cases (Jan2011-Oct2013) and part II-dengue outbreak (Nov2013-Dec2014). Based on reports from Fiji Ministry of Health and reports from World Health Organization (Fiji-MoH, 2014; WHO, 2014), serotype 3 of dengue virus which caused the 2013 and 2014 dengue had not been detected in Fiji for decades.

This newly reemerged serotype of virus may be associated with the differences between results in part I and part II. Another possible cause of the different epidemic levels in those two parts of the study is the significant differences of weekly average maximum temperature and relative humidity. As it was shown in results, maximum temperature and relative humidity were both positively associated with dengue cases. The significant changes of temperature and humidity may also be connected with change of epidemic level of dengue.

In the analysis of relationship between weather parameters and dengue cases, although some of the results differed in two parts of the analysis, the significant effects of weather variations on dengue cases can still be identified, which indicates the possibility of using weather information including rainfall, temperature and humidity to predict the change of dengue epidemiological situation. Although the power of explaining and predicting change of dengue prevalence by weather itself may not be great, together with the routine surveillance, the weather data can still add power in preventing dengue.

5.2 Surveillance system in Fiji

Problems of timeliness, accuracy and completeness were identified during dengue case reporting process. Some of these problems were also discussed in other studies (McIver et al, 2012). Timeliness of reporting was discussed by the interviewees

most frequently. Disease surveillance relies highly on the punctuality of reporting process of dengue cases. Delay of reporting may lead to delay of identifying signs of dengue epidemic, which may cause high risk of being infected of dengue virus in a specific time period. A web-based disease reporting system has been implemented in some countries (Carneiro & Mylonakis, 2011). Instead of reporting cases using telephone or paper forms, with the establishment of network platform health workers can use apps on smart phones or tablets to report disease cases including dengue cases punctually. However, access to Internet in some remote health centers, which was discussed by some health workers during the interviews, can be an obstruction to the implementation of web-based disease reporting system and more research needs to be done to study the feasibility and cost effectiveness of the web-based disease reporting system in Fiji.

Among the cases reported from 2011-2014, only a small proportion were reported with detailed addresses and other demographic characteristics. During dengue surveillance, health workers rely on the demographic characteristics to analyze the epidemical situation. Lack of accuracy and completeness of such information can cause difficulties for the disease surveillance and prevention process. In addition, afterwards epidemiological analysis may have severely biased results if based on inaccurate and incomplete data. Problems in the dengue surveillance system also create difficulties for the estimating associations between weather variables and dengue cases. The level of

significance and magnitudes of effects that weather parameters had on dengue cases can be compromised due to the inaccuracy of data being collected. According to the health workers being interviewed, not all community health workers were fully trained and the awareness of the importance of conducting disease surveillance was still low for them. These lack of training and lack of awareness can also lead to the decreased quality of the data being reported. Different health centers and hospitals in different divisions and subdivisions used different forms for reporting dengue cases and some forms were even created temporarily by health workers, which created huge inconsistency of the content of data being reported. Another possible reason for the compromised quality of reported data is the high mobility of population in Suva (Bedford, 2013). Dengue patients may live far away from the hospital or health center that give them diagnose and patients with lower severity of dengue may only be treated in the emergency department. The high mobility of population and busy schedule in the emergency department created difficulties for health workers to collect all the necessary information of each patient. Used standardization of forms to collect patients information, which can be included in the web-based reporting system, can be one way of solving the inconsistency of collected data. In addition, offering comprehensive training for community health workers and increase their awareness of the importance of disease surveillance can also be helpful with increase of the data quality.

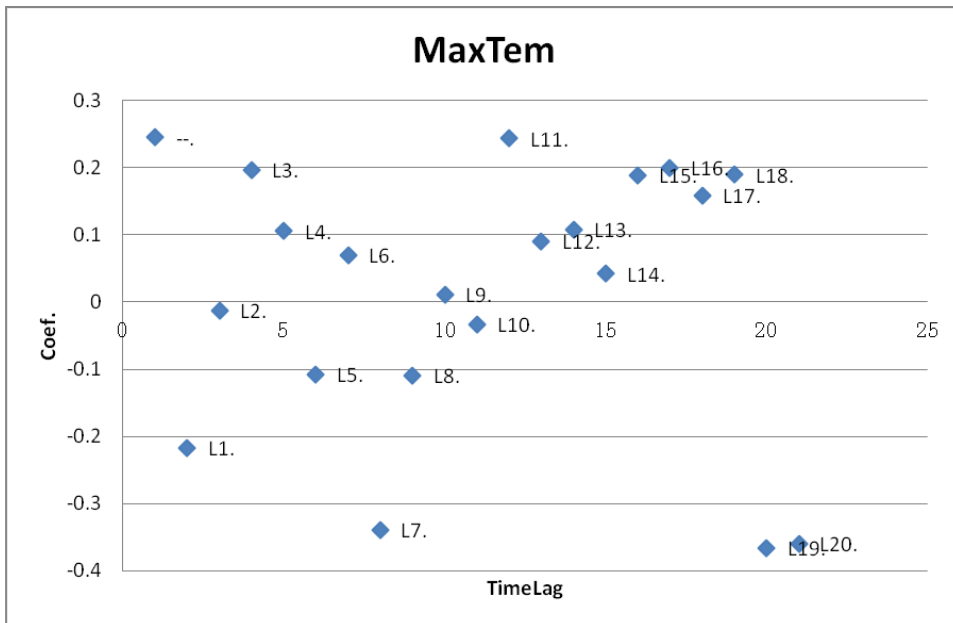
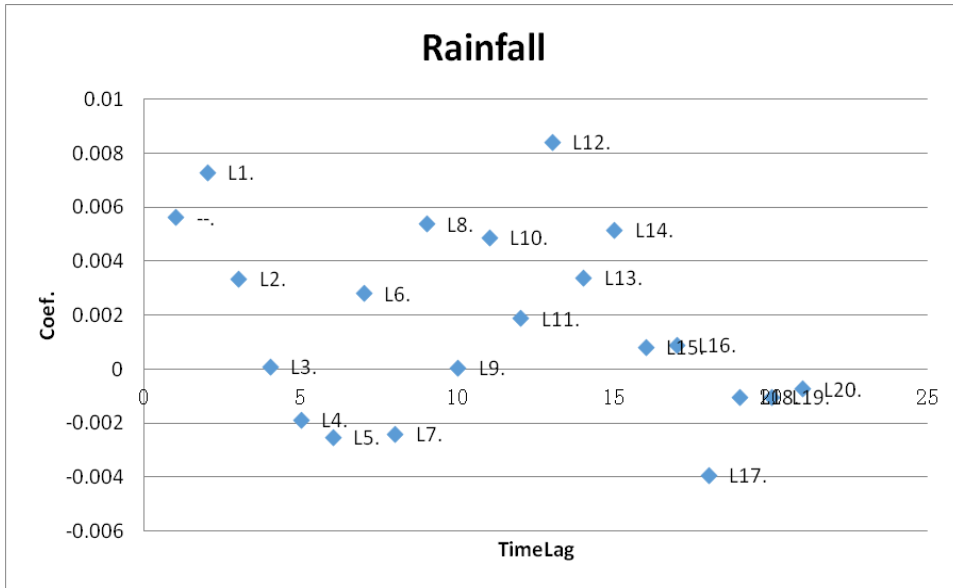
5.3 Study limitations

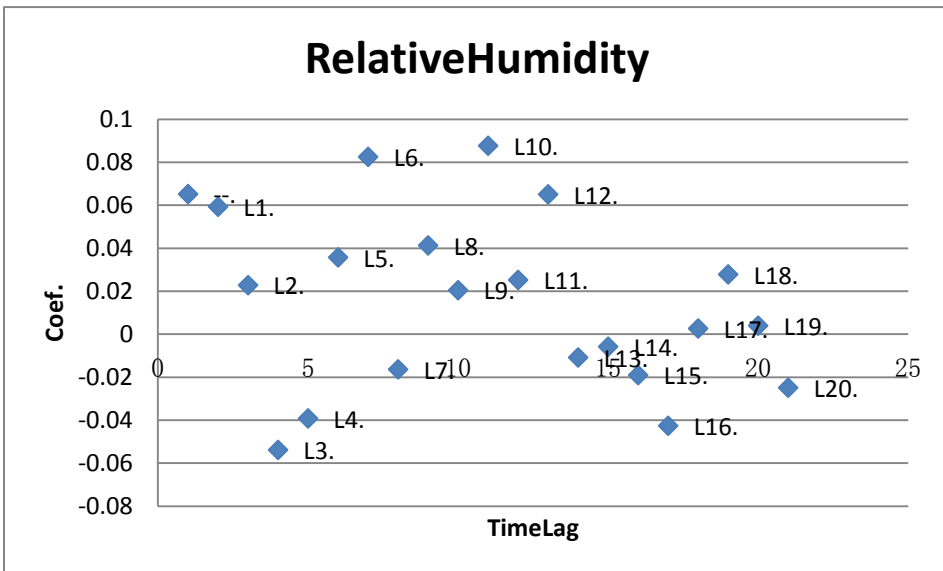
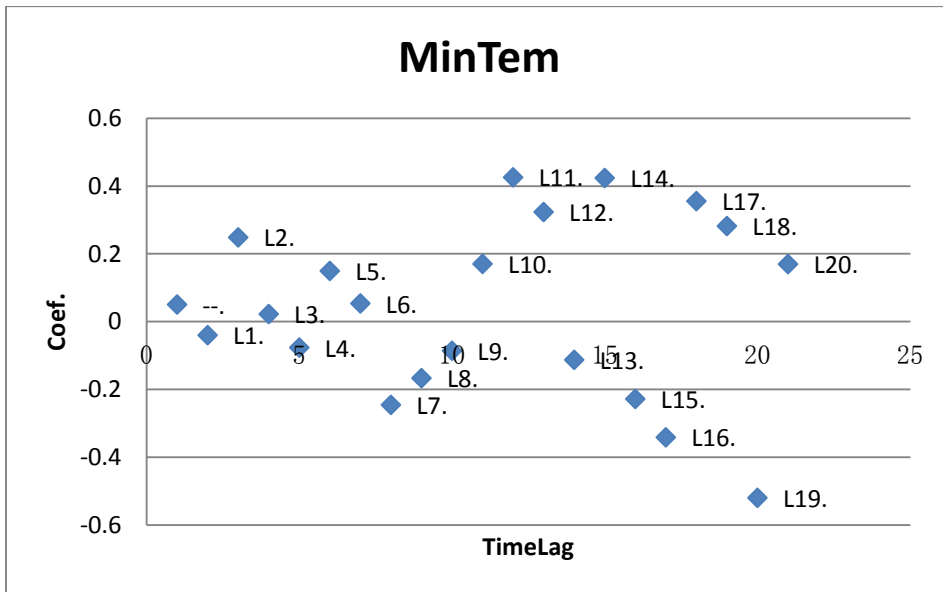
Study limitations exist in both parts of the study. In the analysis of relationship between weather variables and dengue cases, time lags for each weather variable were chosen based on concentration of coefficients of different time lags in the two-way scatter plot by the research. Bias may exist during the selection process. Other relevant time lags may be neglected due to different degrees of concentrations of the time lag coefficients. Besides weather variables analyzed in the study, other weather parameters such as wind speed and atmospheric pressure which were reported in some studies to be significantly associated with dengue cases were not collected in the study data set (Cheong et al, 2013), which could lead to lower power of the regression models. During interviews with health workers in Fiji about surveillance system, no focus group discussions was held due to the conflicts of time schedule of each health worker. All the interviews were conducted one to one. In that case, health workers may only respond to questions that researcher raised and other problems which were not noticed in advance of the interviews may be neglected.

6. Conclusion

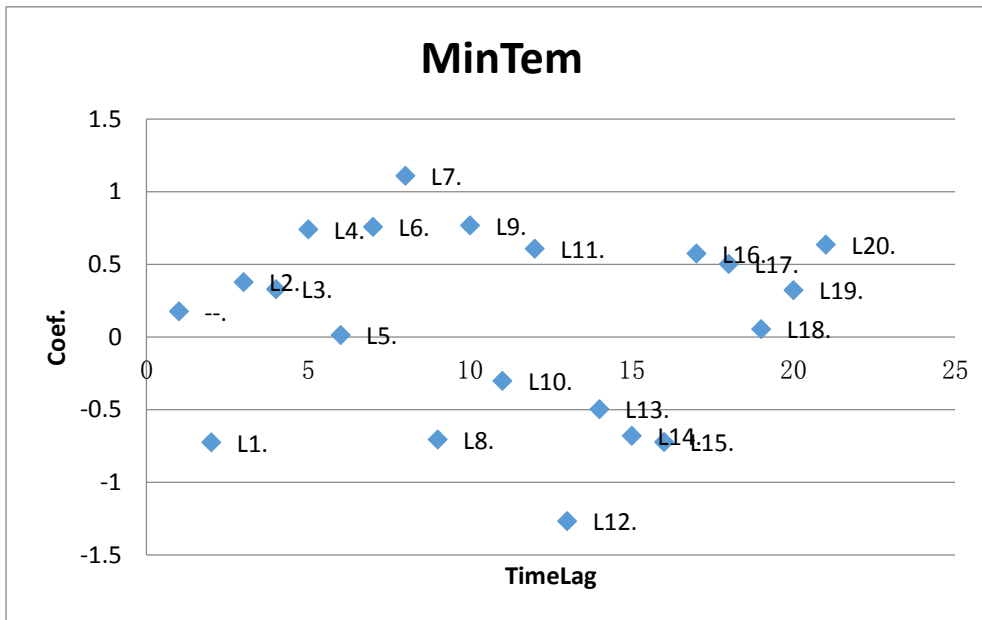
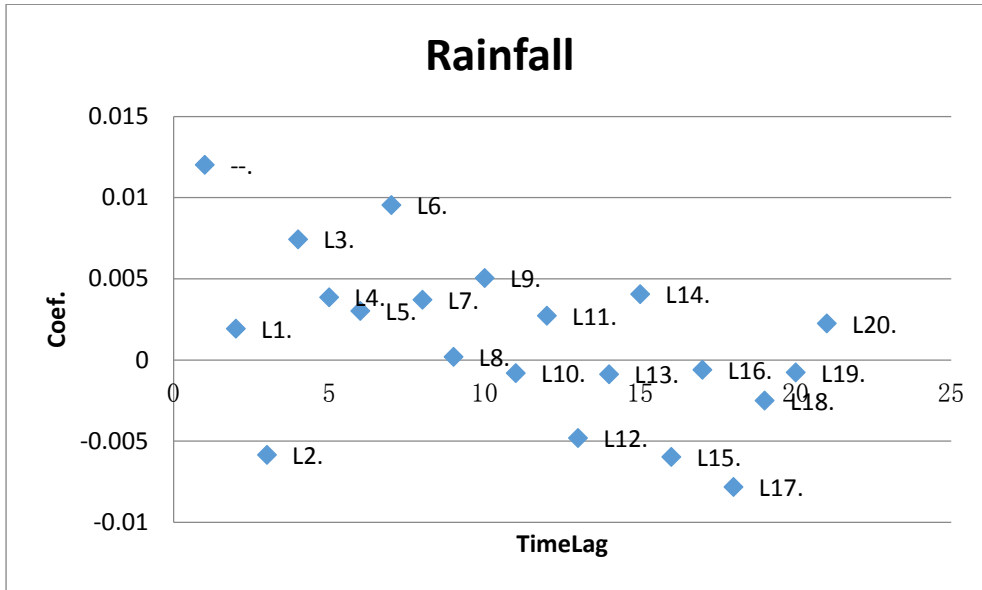
The study showed significant associations between weather variables including rainfall, maximum temperature, minimum temperature and humidity and dengue cases in Suva, Fiji. These associations may establish the foundation of developing a weather-based early warning system for dengue in Fiji. Time lags for each weather variable can also be used in the disease prevention plan. Problems identified in the current surveillance system for dengue include the lack of timeliness and compromised quality in the case reporting process. Web-based disease reporting system and standardized reporting procedures may be useful in improving the surveillance system. A more efficient disease surveillance system can be developed by integrating the effects of weather parameters in the routine surveillance.

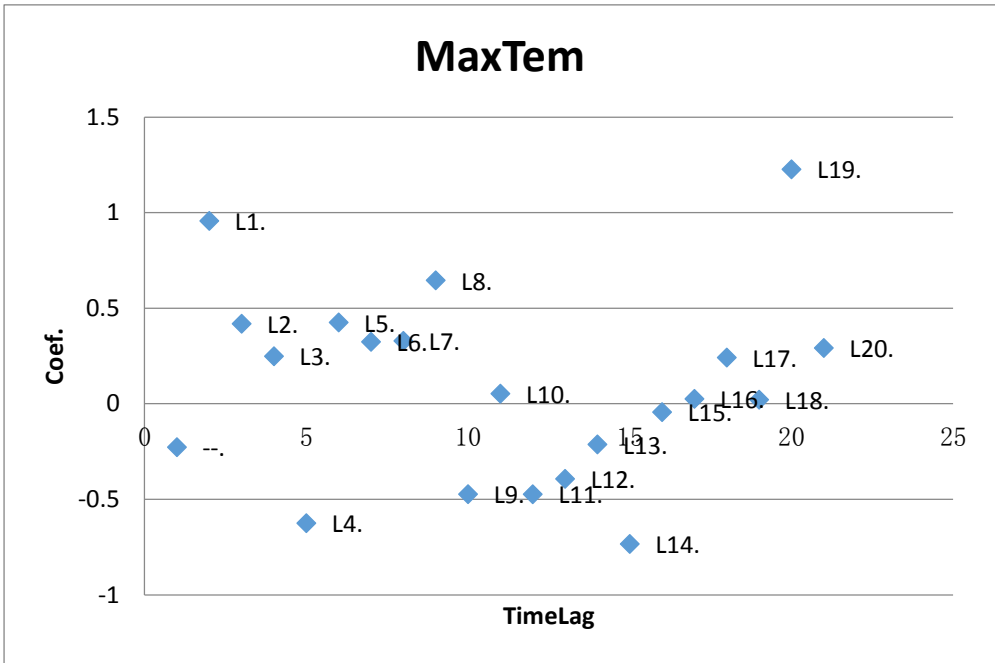
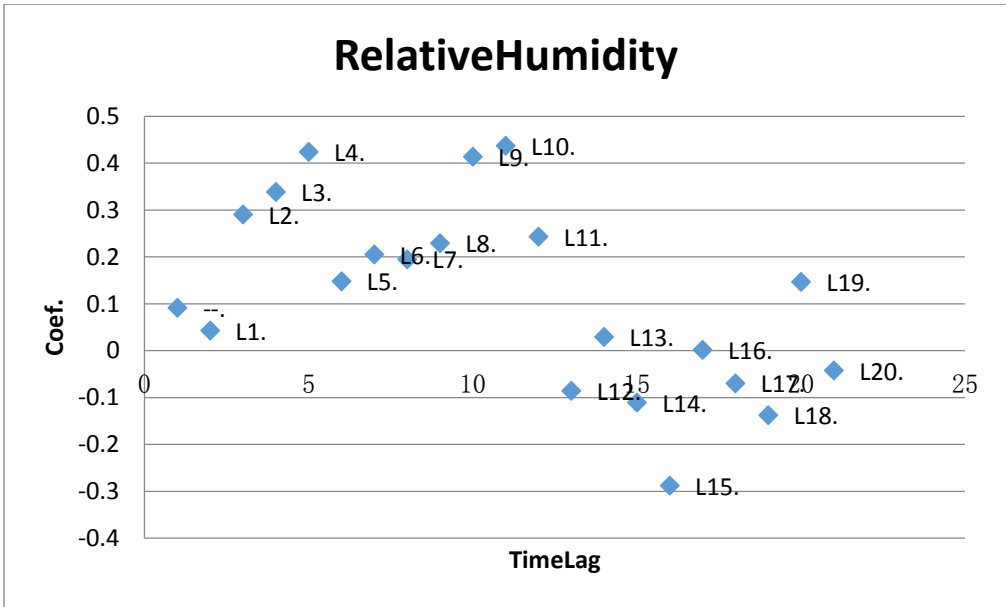
Appendix A Twoway Scatter Plot of Coefficients (2011.01-2013.10)





Appendix B Twoway Scatter Plot of Coefficients (2013.11-2014.12)





Appendix C Interview outline for in-depth interview (health workers)

1. Could you tell me the procedures of identifying suspected/diagnosed dengue patients?

Where did they often be identified?

What are the criteria of defining a patients as suspected dengue patients?

2. What are the procedures of reporting those dengue cases?

What are the criteria of reporting a dengue case?

What kinds of dengue cases you will report, diagnosed cases only or both diagnosed and suspected cases?

Who do you report these cases to and how would you do that?

Who report these cases to you and how were they reported?

3. (for health workers in the medical lab) How long will it take your department to diagnose a dengue case?

4. How many dengue cases did you identify last year?

Where are these cases come from? Are they from only urban areas or both urban and rural areas?

What is the ratio of dengue cases in urban and rural areas?

5. Do you know the early warning system in Fiji, both symptom-based and climate based EWS?

If you know, where do you get this information and what do you know about it?

What is your opinion on this system?

6. What your opinions on the current surveillance system for dengue fever?

Do you think there is any problems in this system? Some procedures that you think is redundant or too complex to follow?

7. How do you think the quality of data your collected?

Is that good or not?

If it is not good enough, how do you think we can improve the quality of data?

In which procedure of the surveillance system do you think the quality of data could be compromised?

Appendix D Interview outline for in-depth interview (patients)

1. Could you tell me how did you be identified as dengue?

Where did you be identified?

Who gave you the diagnosis?

What exams did you take before the diagnosis?

2. Do you know what the procedures of reporting dengue cases are?

What are the criteria of reporting a dengue case?

Who report your cases and how were they reported?

3. What are the common interventions for dengue prevention and detection in your communities?

Is there any health intervention of measures to protect people from dengue?

Any interventions targeting mosquito breeding sits?

Any interventions targeting specific population groups such as people living in extremely poor?

4. What are your attitudes toward these interventions?

Do you follow the intervention? Why or why not?

Do you think those interventions are useful and necessary? Why or why not?

Do you reflect your opinions on these intervention? If they do, what are you opinions? If not, what are the reasons of not reflecting?

5. Do you know the early warning system in Fiji, both symptom-based and climate based EWS?

If you know, where do you get this information and what do you know about it?

Do you think it will be useful to prevent dengue infection and outbreak? Why or who not?

What is your opinion on this system?

6. What your opinions on the current surveillance system for dengue fever?

Do you think there is any problems in this system? Some procedures that you think is redundant or too complex to follow?

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