CARIWIG Case Study Report 10

Dengue Fever in the Belize District

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Summary

- According to the Ministry of Health (MOH 2014), dengue fever (DF) is rising in the Belize District.
- Statistical analysis shows a positive association between precipitation, minimum temperature and dengue fever.
- Climate projections for the 2050s show decreases in mean wet-day precipitation from May to September, with an increase in rainfall variability and heavy rainfall in October and November.
- The general increase in Maximum (Tmax) and Minimum temperature (Tmin) in the 2050s indicates warming for that period.
- The Weather Generator/Threshold Detector outputs show a decrease in the number of days where Tmax exceeds 20°C but does not exceed 32°C- which implies less favourable conditions for DF. However the findings also show an increase in the number of days where Tmin is greater than 18°C and hence more favourable conditions for DF.
- Apart from the possibility of climate related impact on DF occurrence, non-climate issues such as changes in DF classification and reporting over the years 2007-2014, should be kept in mind together with social and economic drivers and conditioning factors.

Aim and objectives

The primary aim of this study was to investigate the impact of climate variability and change on the occurrence of dengue fever (DF) in the Belize District.

Objectives of the study were:

- To determine the effects of climate, in particular precipitation and temperature, on DF occurrence
- To explore the effects of a changing climate in terms of health to communities, decision making, planning, social behaviour and practices in the 2050s
- To discuss consequent repercussions for the health sector as a whole

Which tools were used? How and why?

The CARIWIG weather generator (WG) was used because it provides site specific data (for 100x 30 year runs) for the Philip S.W Goldson International Airport (PSWGIA) station in the Belize District, and corrects biases in Regional Climate Model (RCM) outputs. Future weather scenarios were developed using change factors between the control period of the PRECIS RCM (driven by two different global models ECHAM5 and AENWH) and future 30-year periods centred around the 2020s, 2050s and 2080s. The projected changes in climate give an insight into the future occurrence of DF in the district. The information can equip stakeholders with critical information which will inform planning and science based decision making to alleviate the burden of the disease. The analysis presented here is based on projected climate changes in the 2050s focusing on temperature and precipitation, which are considered important for the sustainable transmission of DF. As well as looking at changes in mean values, WG outputs were used with the Threshold Detector to explore projected changes in the exceedance of relevant thresholds. This analysis used the temperature thresholds associated with DF incidence in Mexico according to Colón-González et al. (2013)- based on the assumption that these relationships are similar in Belize.

The findings

Dengue fever occurrence is often found to be greatest in urban communities. This is the case for the Belize District where DF per 100 people is highest in the most urban community of Belize City followed by the major tourist destination of San Pedro Town on Ambergris Caye (see Appendix 1). Several studies in the region (Depradine and Lovell 2004; Chadee et al. 2006; UWI 2006) have associated the occurrence of DF with precipitation and temperature.

In the Belize District, rainfall and minimum temperature (Tmin) were found to be major factors contributing to the occurrence of DF based on results of a statistical analysis conducted on seasonal datasets for the period 2007-2014, that showed a positive association between rainfall and DF from Sept-Nov and Dec- Feb (where Pearson's Product Moment Coefficient (r) = 0.547 and 0.555, respectively). Similarly, the findings show a positive correlation between DF and Tmin (r=0.723 and 0.527) from Sept-Nov and Dec-Feb, respectively.

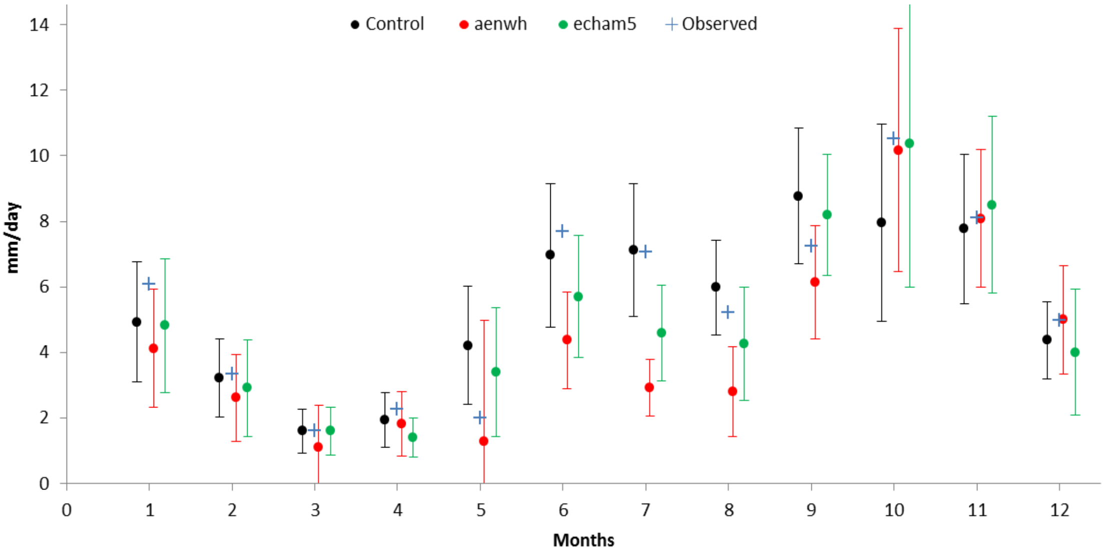

Figure 1. Mean wet-day precipitation for aenwh and echam5 for the 2050s. The control and GCM values are derrived from the of mean 100 WG runs. The lenght of the natural lines (error bars) indicates uncertainty due to variability.

In contrast, there is a negative correlation between DF and Tmax in the Belize District, in all seasons (see Appendix 2). According to the Climate Models considered here, mean wet-day precipitation will likely decrease in May –September in the 2050s (see Figure 1), while an increase in the frequency and year-to-year variability of heavy rainfall is projected for October and November (Not shown).

The general indication for future temperature according to the models, is a likely increase in Tmin (see Appendix 3) and Tmax (not shown) in all months in the 2050s. Colón-González et al. (2013) found that Tmax above 20°C has an increasing effect on DF incidence in Mexico, while Tmax greater than 32°C is associated with a decline in DF incidence. In contrast, Tmin above 18°C is associated with a rapidly increasing incidence. Assuming that these relationships are similar for both Mexico and Belize, the threshold detector outputs show obvious decreases in the number of days satisfying these thresholds, most notably from May-September with less than 120 days within the 30 year 2050s period, while the number of days in all other months range from around 300-700 days (see Appendix 4). A look into the cause of the likely decrease in the joint Tmax threshold reveals that although virtually all days (except in February) are projected to exceed the Tmax > 20°C threshold, there is a major increase in the number of days with Tmax >32°C- accounting for the large decrease in the number of days falling within the critical Tmax temperature range.

On the other hand, the findings show considerable increases in the frequency of days where Tmin exceeds 18°C particularly in Jan-Mar and Nov-Dec with around 828-925 days and 866-890 days in the 2050s, respectively (i.e. the threshold is exceeded on most days). Tmin is also exceeded to a lesser extent in Sept-Oct with around 880-899 days (see appendix 5). There is no change from April-June while a slight decrease is noted in July-Aug for the aenwh forced run. Taking into consideration the findings by Colón-González et al. (2013), the large increases in Tmin noted in the early and latter months of the year may result in increased DF occurrence in the 2050s in the Belize District.

Implications for policy and planning

It is important to understand the association between climate variability and change and its impact on DF occurrence. The development and availability of the CARIWIG tools can help in studying climate sensitive diseases and to improve decision making.

Governments should sustain their responses to DF morbidity although there may be potentially lower DF transmission rates due to low rainfall in the future. As a result of projected decreases in total rainfall from May-September, natural and artificial breeding grounds may become dry due to lack of rainwater recharge. This could be an excellent opportunity for health related stakeholders to engage in continued educational awareness regarding symptoms of the disease so that persons can rapidly recognize signs of the disease and seek treatment. Also, governments can possibly form alliances with community groups to impart a sense of responsibility towards minimizing the risk of the disease in communities. As it relates to the possibility of supplementing water needs through the use of water storage containers during periods of low rainfall, a policy solution can be developed to undertake awareness and communication campaigns to promote proper water storage practices. This would deliver the added benefit of instilling and safeguarding proper hygiene in all communities. Carrying out this activity is essential to alleviate DF morbidity because improperly covered containers can serve as breeding grounds for vectors thus leading to higher DF occurrence.

Apart from potentially reduced DF occurrence caused by larval flushing due to excessive rainfall (McMichael et al. 2003; Taylor et al. 2009), governments should also recognize the contrasting threat of potentially increased DF rates in the future as a result of heavy rainfall and its year-to-year variability. According to Taylor et al.(2009), heavy rainfall gives rise to more breeding sites. In response to the likelihood of increased DF transmission rates due to heavy rainfall, within its strategy government can improve awareness by embarking on campaigns to eliminate artificial habitats by promoting proper garbage disposal techniques. Furthermore, the government and other stakeholders can find ways to enhance the existing epidemiological and entomological surveillance system and implement early warning systems to gauge the timing and burden of an epidemic.

With regards to the increases in Tmax and Tmin projected for the 2050s which could alter mosquito biology (Focks et al. 1995; Taylor et al. 2009), there are several policy actions that can be considered to control the consequent proliferation of DF. According to the World Health Organization , the health sector can capitalize on strategies that enhance DF preparedness and response by improving and undertaking activities such as "risk assessment and mapping, stockpiling and logistics, surveillance and diagnostic capacity" (WHO 2012b, 12). Additionally, fully implementing an Integrated Vector Management (IVM) programme, which is a process focused on making optimum use of resources for vector control (WHO 2012a), can greatly benefit countries with limited resources such as Belize. Furthermore, to manage increases in DF occurrence caused by warming conditions, there is a need for constant capacity building to reorient staff with healthcare services pertaining to the management of DF and increase capacity to cope with population growth.
In terms of likely decreases in the number of days satisfying the Tmax thresholds identified by (Colón-González et al. 2013), policy makers should keep in mind the influence of the upper end threshold of the joint Tmax condition. Although the outputs show a general decrease, health related stakeholders should continue DF awareness efforts because there is still a considerable amount of days which could likely facilitate the potential transmission of DF. As it relates to Tmin>18°C, focalized efforts should be developed to reduce DF occurrence, particularly in Jan-Mar and Nov-Dec when an increase in the number of days satisfying the Tmin threshold is largest. Research should be conducted to investigate the Tmin threshold according to (Colón-González et al. 2013) and its effect on DF in Belize, since the outputs show a sizable increase in the number of days satisfying the Tmin>18°C threshold in certain months.

In addition to the previously mentioned ramification for policy and planning, there are several other considerations that health related stakeholders can participate in to alleviate DF occurrence in the future. Policy makers can use information from the outputs to proactively plan for warming and a decrease in mean wet-day precipitation from May-Sept in the 2050s through public awareness initiatives focused on changing behavioural practices i.e. proper water management practices during warmer months to reduce vector habitats and ultimately decrease DF occurrence in vulnerable communities. Furthermore, health officials should encourage the use of protective mechanisms such as bed nets and insect repellents to curb DF transmission rates. Although these measures are conventional methods that address social and economic conditioning factors, officials should remain cognizant that poverty is a significant factor which can influence the outcome of implementing defense mechanisms which require that families come up with finances to support the additional expenditure. Decision makers should also consider the possibility that the likelihood of more favourable conditions for increased DF transmission in some months of the year could strain health sector resources in the 2050s. Given the results, it is also important for decision makers to consider greater collaboration between the health sector and other stakeholders or ministries to improve accessibility of piped water facilities where it is currently lacking. Governments could also consider prioritising research to determine the true burden of the disease in the Belize District. Additionally, supporting research can be used to plan and coordinate a strategic response while also offering an opportunity for investment as it pertains to international funding.

Aside from climate related drivers, it is also possible that an apparent increase in DF occurrence in the Belize District is due to changes in the DF reporting structure over the years 2007-2014 (see Appendix 6). It is possible that underreporting in previous years could have led to false conclusions that DF occurrence in the past years was low. Additionally, social and behavioural practices contribute to DF occurrence. Similarly, population growth is also likely to have contributed to increases in DF occurrence especially in more recent years. Lastly, the Vector Control Program in Belize could also impact observed DF occurrence since the prevention and control of dengue fever is a primary focus of the program.

Feedback on the tools

The WG and TD tools have been developed using sound science which can aid stakeholders and policy makers in the decision making process as it relates to DF occurrence in the Belize District. The WG and TD tools offer stakeholders the opportunity to plan for various time periods based on short-term or long-term scenarios. Similarly, both tools, especially the WG, afford users the option to select from a wide array of climate variables which increase its utility for various purposes including studies requiring multiple variables (e.g. Dengue Fever) or conversely, focused exclusively on crucial variables. The Threshold Detector is an innovative tool to the region with potential for applicability across sectors and is an asset especially where precipitation and temperature thresholds can influence vulnerability. The availability of both tools promotes efficiency because it reduces the time to obtain raw data and conduct calculations. Nonetheless, there is a great need for tutorials which users can refer to since both tools require considerable technical guidance to operate and properly analyse the outputs.

What more could be done?

More work is needed on understand the interplay and overall balance between the different processes which could variously lead to either an increase or decrease in DF in Belize District (see implications section above). Field work could verify the extent to which social and economic factors contribute to DF occurrence. Field work could verify the extent to which social and economic factors contribute to DF occurrence. A comprehensive policy/program evaluation could be used to determine the impact of existing prevention and control measures on the number of DF cases. It would also be helpful to obtain outputs from more climate models in order adequately reflect modelling uncertainty, as well as consider more greenhouse gas emission scenarios (the results shown here are based on A1B) and additional climate variables such as relative humidity and wind. With respect to the TD analysis, conducting a statistical analysis for the Belize District to identify specific thresholds following the method of Colón-González et al. (2013) could have strengthened this study.

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Organization.

Appendices

Appendix 1: Dengue Fever occurrence per 100 people for selected communities in the Belize District.

Community	Type	2007	2008	2009	2010	2011	2012	2013	2014
Belize City	Urban	1.28	0.69	2.68	5.13	3.92	6.53	11.69	17.87
San Pedro Town, Amberg. Caye	Urban	0.02	0	0.32	0.18	0.18	0.22	1.22	0.64
Caye Caulker	Urban	0.07	0	0.09	0.04	0.02	0.11	0.2	0.14
Ladyville	Rural	0.06	0.04	0.64	0.43	0.36	0.45	0.72	0.88
Hattieville	Rural	0.01	0.02	0.08	0.12	0.09	0.13	0.17	0.21
Burrel Boom	Rural	0.02	0	0.07	0.07	0.11	0.09	0.4	0.32
Lords Bank	Rural			0.03	0.11	0.07	0.15	0.16	0.23
Mahogany Heights	Rural					0.01	0.01	0.01	0.03
Sand Hill	Rural	0.01	0.01	0.09	0.1	0.04	0.13	0.26	0.21
Bermudan Landing	Rural				0.01	0.01	0.01	0.04	0
Biscayne	Rural	0.02	0	0.02	0.04	0.02	0.06	0.14	0.07
Boston	Rural				0.01	0.02	0.01	0.01	0.02
Unknown		0.04	0.02	0.01		0.3	0.01	0.01	
Unknown - Belize				0.02			0.01	0.03	0.02

source: (MOH 2014)

Appendix 2: Person's Product Moment Coefficient and corresponding significance value for seasonal dengue fever occurrence and selected climate variables in the Belize District, for the period 2007-2014.

March-April-May		
	r	*p*
rainfall	0.317	0.445
Tmean	-0.094	0.825
Tmax	-0.522	0.184
Tmin	0.39	0.34

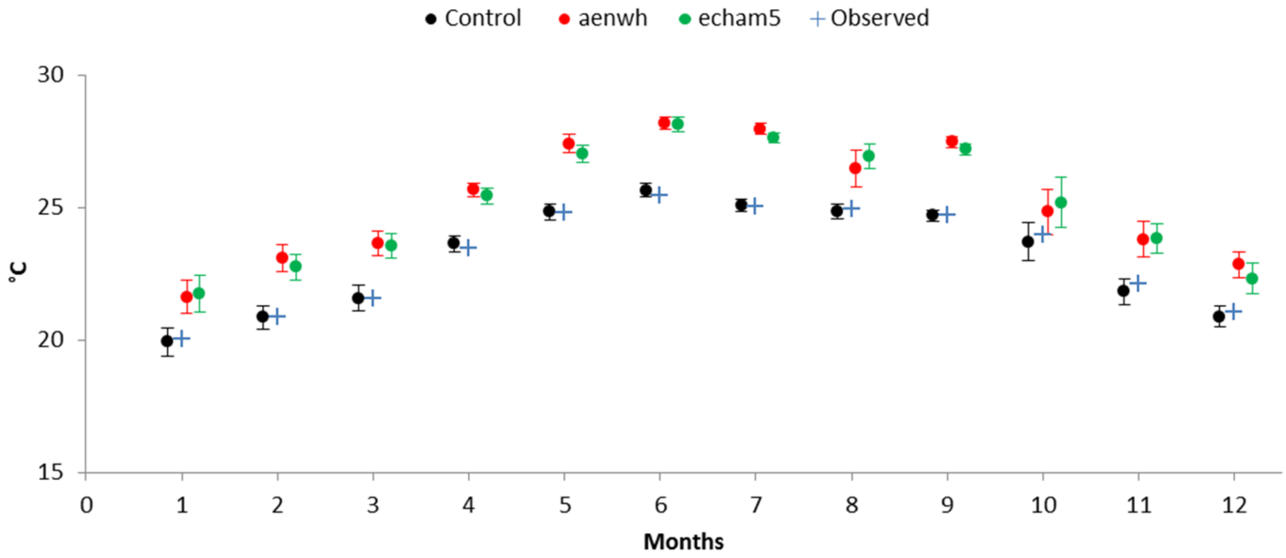
June-July-August		
	r	*p*
rainfall	-0.315	0.448
Tmean	0.215	0.610
Tmax	-0.034	0.936
Tmin	0.408	0.316

Sept-Oct-Nov		
	r	*p*
rainfall	0.547	0.203
Tmean	0.278	0.547
Tmax	-0.553	0.198
Tmin	0.723	0.066

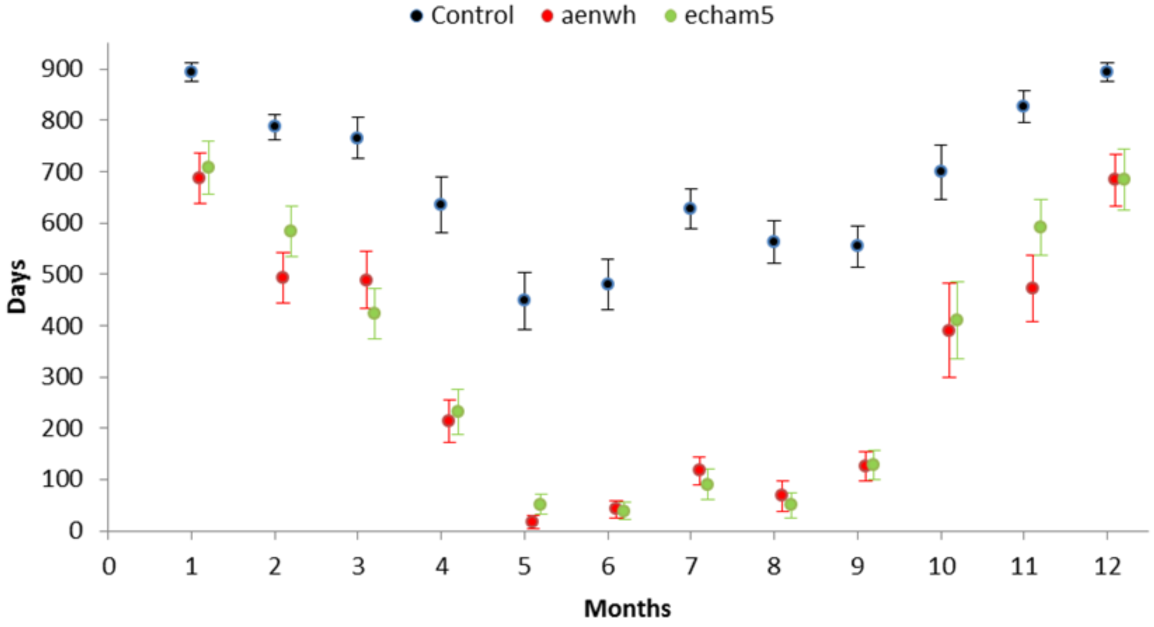
Dec-Jan-Feb		
	r	*p*
rainfall	0.555	0.196
Tmean	0.282	0.540
Tmax	-0.247	0.594
Tmin	0.527	0.224

Source: Climate data provided by the Belize Meteorological Service (BNMS 2014)

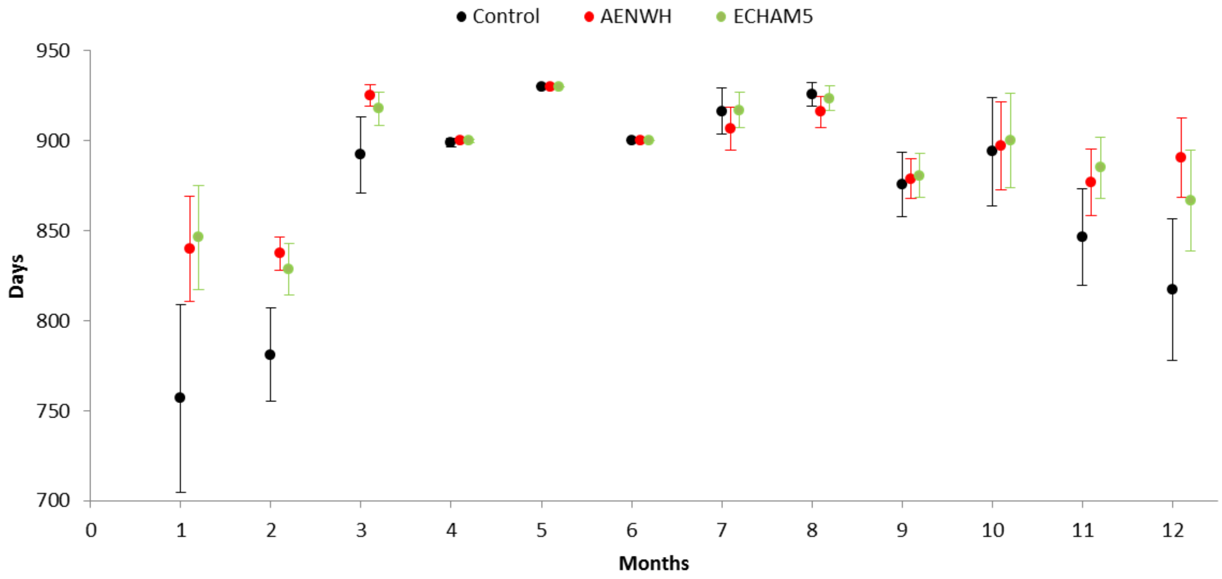
Appendix 3: A comparison between aenwh and echam5 forced run for minimum temperature in the 2050s in the Belize District.



Appendix 4: Joint Tmax threshold-Tmax greater than 20°C less than 32°C- for aenwh and echam5 forced run for the 2050s in the Belize District.



Appendix 5: Minimum Temperature greater than 18°C for aenwh and echam5 forced runs for the 2050s in the Belize District.



Appendix 6: Dengue fever classification in the Belize District for the period 2007-2014.

Classification	2007	2008	2009	2010	2011	2012	2013	2014
Blank	123				82			
[Rejected/Cancelled] - Test not Available			86		23			
Unknown						101		
Dengue						24		
Dengue fever						100		
Dengue fever [classical dengue]						44		
Dengue haemorrhagic fever						2		
DHF*		1						
Hemolysed		2						
IgG Positive				30	31	18		
IgM Positive				38	37	18		
IgM/IgG Positive				76	22	5		
Negative		13	238	498	335	503		
No Form		9						
Not Done		6						
Pending		4						
Positive	39	40	89					
QNS		3						
Confirmed							68	148
Probable							126	148
Suspected (Clinical)							261	228
Suspected(by Test)							1100	1587

The Table above shows that the Ministry of Health only classified positive cases as DF cases in 2007, unfortunately, 123 cases in that year were undocumented. From 2008-2009, new DF cases were categorized as either positive or negative cases; however, several cases in 2008 were not properly recorded or awaiting test results. Starting from 2010-2011, the Ministry of Health reorganized positive DF classification to include testing for immunoglobulin G (IgG) and immunoglobulin M (IgM) antibodies, while maintaining the use of a negative classification where applicable. The use of IgG and IgM antibodies continued through 2012; however, cases were further classified as DF, dengue haemorrhagic fever (DHF) and classical dengue. Most recently in 2013 and 2014, DF cases were redefined as confirmed, probable, suspected (clinical or by test).

Source: (MOH 2014)