Title: Climate Change and Dengue

Research Question: To what extent is climate change responsible for the spread of dengue in Hong Kong?

Subject: World Studies - Health & Development

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Contents:

1. Introduction: **To what extent is climate change responsible for the spread of dengue in Hong Kong?**

As classified by Carbon Brief, climate change should be considered 'the major threat of the 21st century' (Dunne, 2017), with potentially large effects on global health. This paper will explore the possible link between anthropogenic climate change and the increased prevalence of dengue cases in Hong Kong. Emerging evidence suggests certain characteristics of the dengue virus such as its epidemiological (incidence, distribution and control) and hyper-endemic nature facilitate its spread in densely populated regions such as Hong Kong. Furthermore, geographical aspects of Hong Kong that act as drivers of dengue will also be discussed.

To understand the correlation between the biotic dengue and abiotic climate change both biological and geographical data will have to be studied in an integrative way. Information must be drawn from both subject areas in the form of an interdisciplinary approach to allow the depths of the topic to be fully understood thus allowing for a more trusted conclusion. When considering the epidemiological nature of the virus and mosquito, biological resources such as the Centre for Health Protection in Hong Kong will be used. Contrastingly, to understand the change in climate and physical geography of Hong Kong, data and information will be interpreted from local geographical resources such as the Hong Kong Observatory. The Special Administrative Region of Hong Kong has well established resources, such as those mentioned above, which will permit a reliable conclusion to be drawn combining both geographical and biological data.

Impacts of climate change are felt both on a global as well as a local scale, having consequences on all areas of social, political, economic, environmental and demographic life. The increasingly discussed and most prominent issues arising from climate change are presented as a rise in temperature, an increase in the strength and prevalence of natural disasters as well as the increased incidence of infectious diseases, all of which are encompassed in one or more of the above sectors of life. Each of these effects of climate change has a different consequence on global health. This paper will examine the increased prevalence of infectious diseases such as dengue, causing long-term health impacts in the region of Hong Kong.

2. Dengue

2.1 The nature of the dengue virus and vector:

Dengue is a hyper-endemic disease ('one that is constantly present at a high incidence' (Ncbi.nlm.nih.gov, 2019)) highly sensitive to climate change and will therefore potentially have large impacts on global and national economies as well as on human health.

Dengue is a single stranded RNA virus with 4 different serotypes (DEN-1, DEN-2, DEN-3 and DEN-4). DEN-2 is the strand of the virus associated with severe dengue and other serious clinical issues. However, DEN-1 is the most common serotype found in Hong Kong. In 2018, 24 out of the 28 reported dengue cases were found to be caused from the dengue virus serotype 1 (Icidportal.ha.org.hk, 2019).

As studied in IB Biology, polymerase chain reaction can be used to identify if a patient has the virus and differentiate between different dengue serotypes. The molecular test allows the genetic material of dengue virus in the blood to be detected (Labtestsonline.org, 2019). Such aspects of the virus' nature could not be fully understood if only inspected from a geographical point of view.

2.2 Dengue transmission:

Dengue is defined by the United Nations World Health Organization (WHO) as a mosquito-borne viral infection. It is known as an arboviral disease, meaning it is 'transmitted to humans by the bite of infected arthropods (insects)' (Health.ny.gov, 2019). In the case of dengue these vectors are female mosquitoes' part of the Aedes aegypti and Aedes albopictus species, which carry the virus for 4 to 10 days before becoming capable of transmitting it for the rest of their life. Female mosquitoes require proteins from human blood in order to develop their eggs, which are then deposited in man-made, artificial containers (Lozano-Fuentes et al., 2012), making the females the virus transmitters.

When a human host is infected with the virus, it leads to dengue and seldom to the potentially fatal, severe dengue. Annually, severe dengue causes an estimated 500,000 people to require hospitalization, of which 2.5% of cases are fatal (Who.int, 2019). However, mortality rates caused from severe dengue have decrease from above 20% to below 1% (Who.int, 2019).

Both species A. aegypti and A. albopictus are vectors of several pathogens, (microorganisms such as bacterium or viruses that can cause a disease). The pathogens carried by these mosquitoes are responsible for past epidemics of yellow fever and the 2015 Zika outbreak affecting large parts of North and South America and certain regions of Southeast Asia.

Both symptomatic (presenting symptoms) and asymptomatic (presenting no symptoms) patients are carriers of the virus. If a non-infected mosquito bites a human host, they will act as a source for the vector to get infected and pass on the disease to the next person that is bitten – these patients can be considered essential multipliers for the virus.

The A. aegypti mosquitoes are day time feeders venturing out in early mornings or evenings. They are well adapted to urban and indoor areas, 'lying low under beds and wardrobes' (Mc Sweeney, 2016) ready to approach their victims from behind, biting ankles and elbows. In megacities such as Hong Kong these times correspond with rush hour, when waves of commuters are out. As a result of more people being exposed to the vector, the virus transmits faster and more frequently. As well as their timeliness the insects are 'sip feeders' and therefore as Carbon Brief put it favor 'small blood meals from lots of people' (Mc Sweeney, 2016) again, increasing the potential for the virus to spread. The nature of the vectors makes them more prolific at reaching larger groups of people and therefore at spreading the virus.

A. aegypti, an arthropod of growing importance, is vastly affected by changes in its environment on a global and local scale. This family of mosquito is traditionally found equatorward, in tropical and sub-tropical climates such as Southeast Asia, where the first dengue epidemic was recognized in the Philippines and Thailand in the 1950's (WHO, 2018). Further research from the WHO shows that Ae. Aegypti vectors thrive in urban areas and favor breeding in man-made objects such as tires, flower pots or buckets. Such containers can quickly get filled with rainwater and can be exploited for the immature (larval and pulpal) stages of A. Aegypti. The exploitation of artificial containers for the deposit of the vectors eggs, could explain, in part, the spreading of the virus to new areas such as Europe as a result of trade. This aspect of the vectors breeding nature may be linked to a higher risk of contracting dengue in densely populated urban areas with abundant artificial breeding grounds. This may act as an reason for the prospering of the vector in regions such as Hong Kong, the fourth most densely populated city in the world (AVPN, 2019), and explain the increase in number of dengue cases there.

In such urban areas, the chance of catching or transmitting the virus rises due to the dense population, but urbanization can also be considered a factor affecting it's spread. With urban development comes an increase in infrastructure and construction creating more breeding grounds for the vectors but also a rise in the inwards flow of people, increasing the population density. Urbanization and population density are more concerning to urban rather than rural areas, theoretically making dengue more prominent in these highly populated urban regions. Population density and urbanization must therefore be considered contributing factors to the spread of the dengue virus yet, neither of them are related to climate change.

As a climate sensitive disease, the burden that dengue imposes on both global and local health, is expected to grow with the changing climate. Both 'long-term climate change and shorter-term weather events' are likely to 'influence the emergence, distribution and incidence' of the virus (Lancet Countdown to 2030, 2019). As explained by the Lancet Countdown on health and climate change, in order to understand the epidemiology (incidence, distribution and control) of the dengue virus several factors should be taken into consideration: such as 'behavioral, demographic, socioeconomic and topographic' factors explaining the increasing spread of dengue on a global or local scale (Lancet Countdown to 2030, 2019).

This information supports the argument that the rise of dengue in Hong Kong could be attributed to factors other than climate change such as the geographical factors previously mentioned. More precisely towards the case of Hong Kong's changing geographical environment, these factors may encompass for example, urbanization, increased population density, trade – allowing the mosquito to colonize internationally to new cooler regions. The extent to which climate change alters conditions favorably to the breeding of the mosquitoes, can debatably be a key factor to this rise in dengue, however not the only one to consider.

2.3 Distribution of dengue:

On a global scale dengue has seen an increase in transmissions since the 1950's with now more than 55% of the global population at risk (Lee et al., 2018). The rising prevalence of the two primary vectors carrying the virus has caused the transmission of dengue to increase by 9.4% since the 1950's (Lancet Countdown to 2030, 2019).

As per stated by the WHO, '3.9 billion people in 128 countries, are at risk of infection with dengue viruses' (Who.int, 2019). Distribution trends have vastly grown since the 1970's, the prevalence of severe dengue has multiplied by 10 and is now considered an endemic disease in over 100 nations (Who.int, 2019). In addition to an increase in the number of dengue cases, the virus has spread geographically and threatens Europe with, previously unexperienced, 'explosive outbreaks' (Who.int, 2019). The vectors innate adaptive capacity and 'ability to shelter in microorganisms' (Who.int, 2019) allows it to spread to such new areas of the world and survive in different, more temperate climates such as that of Europe.

Since 2016, 63% of the global population lived in areas where the mosquito A. aegypti is found. This, therefore, puts more than half of the global population at risk of contracting infectious, arbovirus diseases such as dengue, yellow fever, zika or chikungunya all of which are also transmitted by the A. aegypti or A. albopictus mosquitoes.

3. Hong Kong Environment:

3.1. Hong Kong climate:

The Special Administrative region of China has 'hot and humid' (Weather.gov.hk, 2019) summers with temperatures often exceeding 31 Degrees Celsius in afternoons and tends towards a temperate climate for the rest of the year. It is located on the South Coast of China near the Pearl River delta and the south China Sea.

Hong Kong has a natural harbor increasing its exposure and vulnerability to open waters and weather events. Having an oceanic climate, Hong Kong is 'vulnerable to heavy downpours' (Dsd.gov.hk, 2019) and tropical cyclones typically during the months of July and September (Weather.gov.hk, 2019). Its geographical location, causing high temperatures and annual precipitation rates of 2,200 mm, (Dsd.gov.hk, 2019) positions the region at high risk for dengue because of the vectors attraction to hot and humid regions.

3.2 Environmental causes of dengue in Hong Kong

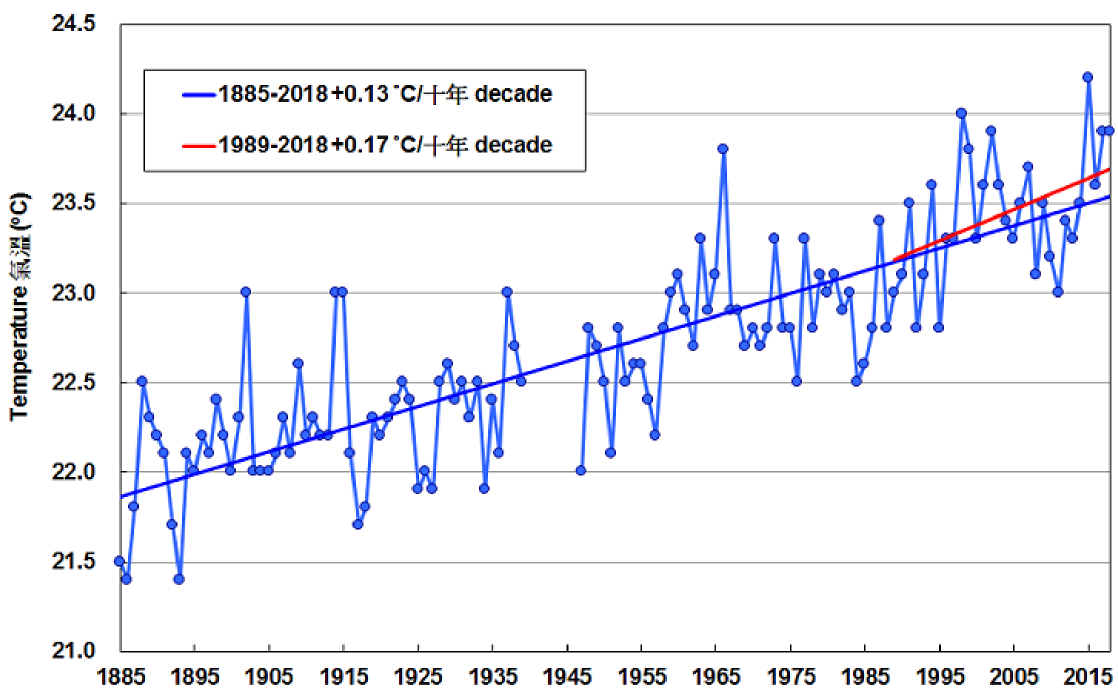

Fig. 1. Changing temperatures of Hong Kong since 1885 *(Hko.gov.hk, 2018)*

Figure 1 (Hko.gov.hk, 2019) shows the rise in the average temperature of Hong Kong since 1885, with the rate of increase reaching 0.17 Degrees Celsius per decade since 1989. The increase in average temperature on a global scale as well as that of Hong Kong, can be due to a hike in greenhouse gas emissions. Increasing emissions subsequently decreases the amount of long wave radiation being sent back out of the atmosphere. This causes a rise in sea surface temperatures thus increasing chances of precipitation and extreme weather such as tropical cyclones. These climactic pressures, as a result of climate change, can cause the threat of dengue and similar vector borne diseases to grow.

A temperature rise of only 1 degree Celsius will enable the atmosphere to retain 7% more water vapor (Chen Yongqin, 2017). Such an increase in temperature results in a rise of moisture evaporation and condensation, leading to cloud formation and subsequent precipitation. Threats of increased precipitation could result in floods as bad as those in the region of Shenzhen in 2014, which caused 80 million Yuan worth of damage (Huifeng and Lo, 2014). It may also cause destruction or left-over stagnant water, thus attracting arboviral mosquitoes to start their breeding. This positive feedback loop of increasing emissions leading to increased precipitation and therefore breeding grounds has the potential to create a rise in the spread of dengue. Human activity being at the start of this loop suggests that anthropogenic climate change in fact does create a changing environment in Hong Kong; one which favors conditions for the development of breeding grounds of A. aegypti and A. albopictus. This evidence therefore suggest anthropogenic climate change does play a part in the increasing spread of dengue in Hong Kong.

The threat of heavy rainfall and floods in Hong Kong poses a major threat to the region. Not only when considering the damage that will be caused but also the long-term effects of increased stagnant waters. The conclusion of a drainage master plan study, undertaken between 1994 and 2010, suggested Hong Kong required short to long-term drainage strategies to meet standard flood prevention requirements (Drainage Services Department, 2019). In 2013, the Drainage Services Department of Hong Kong admitted to poor and aged drainage systems being a cause for flooding, due to its low discharge capacity. The threat of stagnant waters may be the shared consequence of several factors such as the regions geographic location, making certain weather events inevitable and its lacking drainage systems.

As stated by the United Nations Environment sector in 2017 global greenhouse gas emissions reached ‘a record high of 53.5 $GtCO_2e$’ with Hong Kong emitting 6.394 metric tons of Carbon Dioxide in 2014 (Data.worldbank.org, 2019). With the continued growth of emissions, frequent heavy rainfall and extreme weather events will continue to pose a threat of floods in Southern China, mainly in the Pearl River Basin and Hong Kong at its tip (Chen Yongqin, 2017). Subsequently this creates a more suitable environment for the breeding of the dengue vectors.

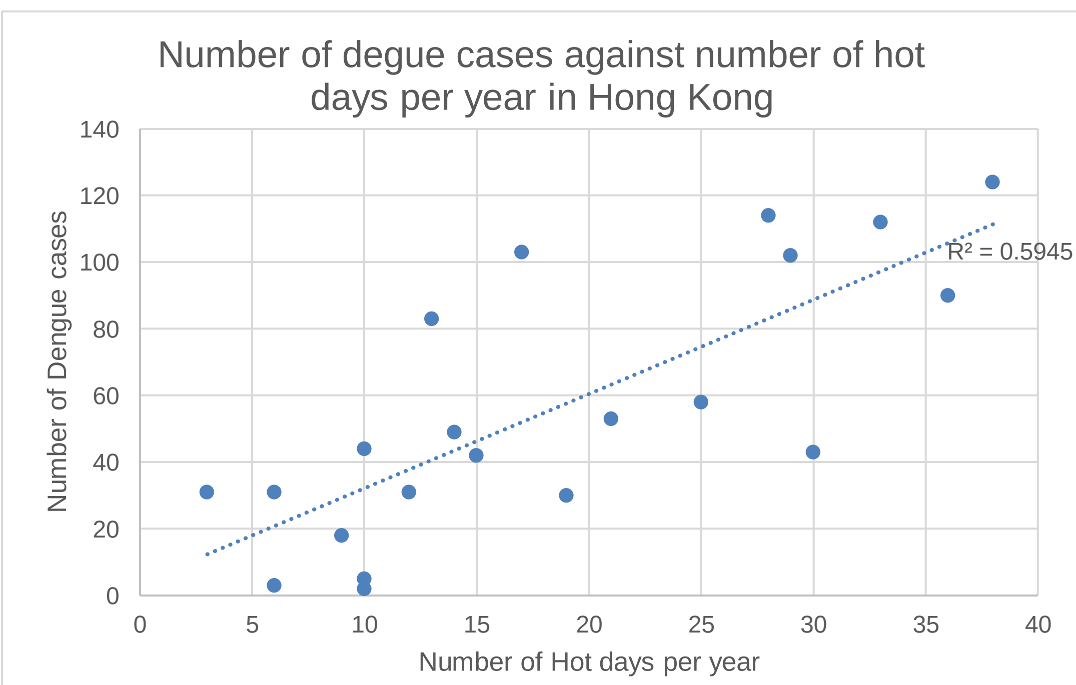

Fig. 2. Number of dengue cases against number of hot days per year in Hong Kong (Hko.gov.hk, 2019), (Chp.gov.hk, 2019), (Icidportal.ha.org.hk, 2018) and (Citeseerx.ist.psu.edu, 2008).

Figure 2 shows the positive correlation between an increase in hot days and an increase in dengue cases in Hong Kong. To find the correlation coefficient R and determine the strength of the relationship between the two variables the value of R^2 (0.5945) must be square rooted, giving a value of 0.771056. A result of 0.70 or above would suggest a strong correlation. Figure 2 would therefore support the hypothesis that an increase in the number of warmer days is responsible for the increase in dengue cases in Hong Kong. Yet, although there is a correlation it does not prove that the cause for such an increase are warmer days; there is potential for other causes.

Arguably one can consider Figure 2 to have too little information. The data is taken over the past 20 years however this may be too short a time period to be able to make a valid conclusion from the graph. There is evidence from the Hong Kong Observatory in Figure 1 proving that Hong Kong has been affected by warming temperatures since 1885 which could provide supporting evidence that the number of hot days has been increasing. This could therefore validate the conclusion drawn from Figure 2 – Hong Kong has been affected by a changing climate, and as a result of this, dengue cases there have risen.

3.3 Changing population of Hong Kong causing dengue:

Another important factor, other than climate change, capable of affecting the spread of dengue and other arbovirus diseases, is the changing population. Based on a global population of around 8.5 billion, the number of people exposed to the virus could rise by 2.5 billion between 2061 and 2080 (Mc Sweeney, 2016). Dr Andrew Monaghan, scientist at the National Centre for Atmospheric research in Colorado, remarks on the threat that ‘climate change and population growth will likely increase the percentage of humans exposed to this (A. aegypti) important virus vector mosquito’ (Mc Sweeney, 2016). He states that ‘areas with better socioeconomic conditions tend to have fewer breeding sites and lower human exposure’ (Mc Sweeney, 2016). However, when considering the region of Hong Kong whose socioeconomic conditions are considerably high, Monahan’s statements may be arguable. The Special Administrative region is considered to be the freest economy in the 2019 index of economic freedom, with a score of 90.2 (Heritage.org, 2019). Additionally, with a GDP of 341.4 billion USD in 2017 and a score of 0.933 on the human development index (Hdr.undp.org, 2017), one should see Hong Kong as a region of high socioeconomic conditions. Therefore, when studying the increasingly high number of dengue cases and recent outbreaks in the region Monaghan’s argument must be debated. Although it is true that with higher socioeconomic conditions comes higher capability to prevent and control the development of such disease and vectors, the case of Hong Kong defies this theory. Thus, the spread of dengue in Hong Kong must be a consequence of other factors such as the change in climate and population growth rather than because of its socioeconomic positioning.

Hong Kong accommodates 6,300 people per square kilometer (Worldpopulationreview.com, 2019). As anthropophilic vectors, A. aegypti and A.

albopictus, favor human hosts, an aspect of their nature which increases the spread of dengue fever, especially in a richly populated area such as Hong Kong. This reason for the spread of dengue is not related to climate change but instead to the epidemiological nature of the vectors. A study held in the Chinese region of Guangzhou north of Hong Kong, revealed the higher chance of dengue outbreaks in urban areas rather than suburban or rural. The study found that 'urbanization had a significant impact on the ecology of A. albopictus' (Li et al., 2014), and explained the faster development of larvae, higher adult emersion rates and longer lifespans in urban areas. Although this study was conducted in Guangzhou, the results are applicable to Hong Kong, as both regions have similar climates and levels of urbanization. This study suggests the importance of urbanization, unassociated to climate change, in the spread and development of the dengue vectors A. albopictus and A. aegypti.

4. <u>The provenance of the dengue virus in Hong Kong:</u>

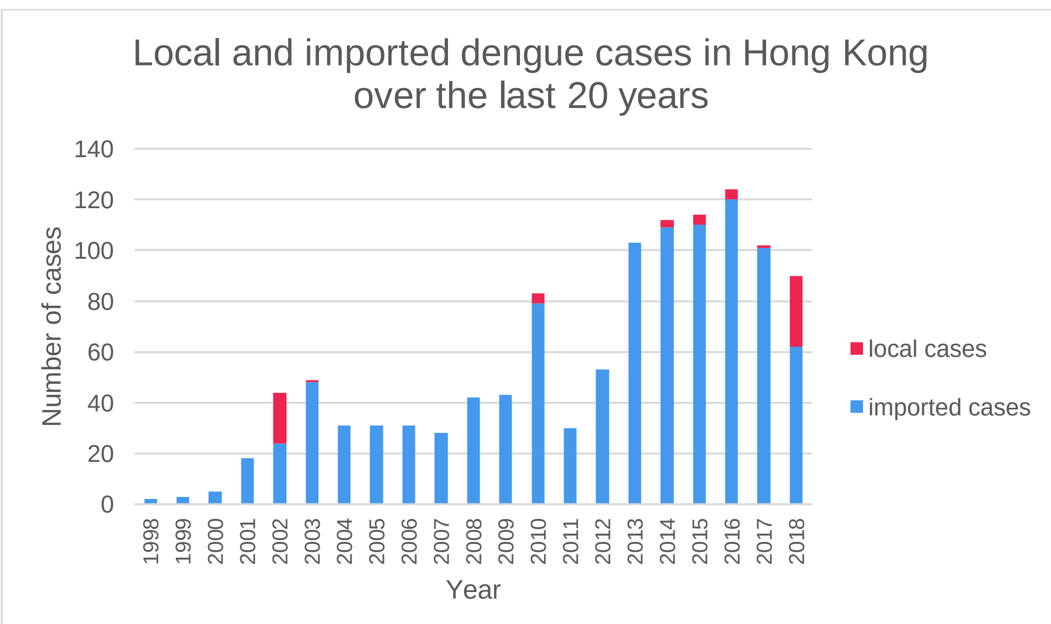

Fig. 3. Local and Imported dengue cases in Hong Kong over the last 20 years.

The data from the Centre for Health Protection in Figure 3 reflects the rise in the number of dengue cases reported in Hong Kong over the past twenty years. It shows that the number of local cases rose noticeably in 2018 yet, the large majority of cases reported since 1998 have been imported. The graph of Figure 3 indicates that there is an increase in numbers of people returning to Hong Kong already infected with the virus. If the virus is imported the patient would have contracted it elsewhere consequently it would have nothing to do with the changing environment of Hong Kong. This could suggest that although evidence from the Hong Kong Observatory proves the region has been affected by climate change, it is not the cause behind this spread of dengue, as the virus is not contracted within Hong Kong.

However, the rise of local cases in recent years, particularly in 2018, could be due to the virus's ease to develop in the region. Of the 90 cases reported in Hong Kong in 2018, 28 of them were classified by the Centre for Health Protection, to have been locally contracted. The rise of imported dengue cases over the years could be the cause for this sudden increase of local cases in 2018. As per the nature of the virus, if a carrier is bitten by a mosquito, he too will become a carrier and therefore a vector. With more people coming to Hong Kong carrying the virus the spread of dengue is expected due to the high chances of these carriers being bitten by a mosquito who will then be able to transmit the virus for the rest of their lives. Due to Hong Kong's densely populated urban environment and favorable climate, the survival and development of vectors is involuntarily facilitated. Figure 3 suggests that the reason behind the rise in dengue in Hong Kong is more due to the fact that the virus is being imported by travelers than it is due to climate change.

5. Conclusion: **To what extent is climate change responsible for the spread of dengue in Hong Kong?**

The extent to which climate change is responsible for the spread of dengue in Hong Kong is debatable, not only because of other key drivers but because one must also take into account the human response to the changing climate. An increase in rainfall may lead to a rise or drop of water storage containers, thus to the possible creation of breeding grounds. If climate change were to be the major contributor, actions to limit it could act as a possible way to reduce the spread of the dengue virus as well as other climate sensitive diseases.

As mentioned in the Lancet Countdown on health and climate change 'disease occurrence is determined by a complex composite of social and environmental conditions' (Lancet Countdown to 2030, 2019). When considering Hong Kong this can be applied after studying the regions vast urbanization, high population density and changing climate. However, in this case the extent to which climate change is the key driver is fairly weak. Because the majority of dengue cases are imported into Hong Kong the spread of the virus cannot be a result of climate change in the region. Yet, one cannot deny that although it may not initiate in Hong Kong dengue is allowed to develop and spread locally due to the favorable conditions stemming from climate change.

6. Appendix:

Year	total cases	imported cases	local cases	mean temp	cold days	hot days
1998	2	2	0	24.0	11	10
1999	3	3	0	23.8	11	6
2000	5	5	0	23.3	17	10
2001	18	18	0	23.6	7	9
2002	44	24	20	23.9	11	10
2003	49	48	1	23.6	8	14
2004	31	31	0	23.4	21	6
2005	31	31	0	23.3	27	12
2006	31	31	0	23.5	14	3
2007	58	28	0	23.7	9	25
2008	42	42	0	23.1	32	15
2009	43	43	0	23.5	22	30
2010	83	79	4	23.2	21	13
2011	30	30	0	23.0	25	19
2012	53	53	0	23.4	21	21
2013	103	103	0	23.3	14	17
2014	112	109	3	23.5	21	33
2015	114	110	4	24.2	7	28
2016	124	120	4	23.6	21	38
2017	102	101	1	23.9	9	29
2018	90	62	28	23.9	21	36

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