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Vital Surveillances

Aedes Surveillance and Risk Warnings for Dengue — China, 2016−2019

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ABSTRACT

Introduction: *Aedes* surveillance plays an important role in the risk warning and control of dengue in China. This study analyzed *Aedes* larval density and its indicated dengue risk in 23 provincial-level administrative divisions (PLADs) from 2016 to 2019 to provide scientific evidence for sustainable dengue management (SDM) in the future.

Methods: The Breteau index (BI) and Mosq-ovitrap index (MOI) methods were utilized for *Aedes* larvae surveillance in 23 PLADs with 3 categories based on dengue risk stratification and *Aedes* distribution. BI and MOI were calculated and then dengue risk warning was carried out for the guidance of SDM in these PLADs based on the findings of *Aedes* surveillance.

Results: The seasonal fluctuations of *Aedes* larval density were similar in six class I PLADs during 2016–2019, and the density of *Aedes* larvae was relatively high in the PLADs of Zhejiang, Hainan, and Fujian while it was relatively low in Yunnan and Guangdong. Except Shanghai and Jiangsu, the BI of all other class II PLADs had reached the dengue transmission threshold during the study period. In class III PLADs, the BI had reached dengue transmission threshold in most months in Shandong and Hebei during the study period. The MOI was higher than 5 from June to September in all the studied years in Guangdong and was higher in most studied years in Hunan. The MOI of Beijing in August reached dengue transmission or outbreak threshold from 2017 to 2019.

Conclusions and Implications for Public Health Practice: Most class I and class II PLADs were at risk of dengue transmission during the surveillance months, 2016–2019. Precise *Aedes* surveillance and risk warnings should be carried out in specific PLADs so as to provide scientific basis for SDM in the future.

INTRODUCTION

In recent years, *Aedes*-borne diseases such as dengue (*1*), Zika, chikungunya, and yellow fever pose a serious public health threat. Globally, two species of *Aedes* mosquitoes, *Aedes aegypti* (L.) and *Ae. albopictus* (Skuse), play an important role for the transmission of diseases mentioned above. Under the impact of some natural and social factors such as climate and environmental change (*2*), urbanization (*3*), and globalization (*4*), etc., the distribution areas of *Ae. aegypti* and *Ae. albopictus* in China expanded in recent years (*5*–*6*), which has created a serious challenge to public health and the well-being of Chinese populations.

In order to meet the above challenges effectively, the theory of sustainable vector management (SVM) was proposed in 2004 (*7*) and was then continuously detailed and applied in *Aedes*-borne diseases control. Since the beginning of 2015, the central government transfer payment project of dengue has supported a systematic surveillance of *Aedes* mosquitoes, providing a basis for the control of *Aedes*-borne diseases in China. This paper introduces the progress of *Aedes* surveillance and its indicated risk based on surveillance data from 2016 to 2019. The findings will lay a solid foundation for sustainable dengue control in the future.

METHODS

According to the guidelines for dengue prevention and control (2014), 23 surveillance PLADs were classified into 3 categories according to dengue risk stratification and *Aedes* distribution in China.

Class I areas included six PLADs (Guangdong, Yunnan, Guangxi, Hainan, Fujian, and Zhejiang) with several dengue outbreaks during the past years; class II areas were ten PLADs (Shanghai, Chongqing, Jiangsu, Anhui, Jiangxi, Henan, Hubei, Hunan, Sichuan, and Guizhou) with reported indigenous dengue cases and/or relatively high dengue risk; class III areas were seven PLADs (Beijing, Hebei, Shanxi, Tianjin, Shandong, Shaanxi, and Liaoning) with imported dengue cases reported and evidence of *Aedes* distribution.

For the density index of *Aedes* larvae surveillance, Breteau index (BI) and Mosq-ovitrap index (MOI) were utilized in this study where BI=(the number of positive containers or other water bodies per houses inspected)×100, while MOI=(positive ovitrap against the total number of effective ovitraps inspection)×100.

Surveillance was carried out twice a month with an interval of 10–15 days during mosquito activity season in Class I areas. It was conducted once a month from May to October in Class II areas, and from June to September in Class III areas.

According to the results of *Aedes* surveillance, dengue risk levels were estimated as the following: when BI<5 and/or MOI<5, dengue transmission is negated (no risk); when 5≤BI<10 and/or 5≤MOI<10, sporadic dengue can occur (low risk); when 10≤BI<20 and/or 10≤MOI<20, dengue outbreak may take place (medium risk); when BI≥20 and/or MOI≥20, dengue epidemic is imminent (high risk).

When BI≥5 and/or MOI≥5, a control plan for *Aedes* was formulated and sustainable *Aedes* management (SAM) measures were carried out, including targeting mosquito prevention, management of breeding sites, and adulticiding if necessary, to reduce the *Aedes* density below the dengue transmission threshold (BI<5 and/or MOI<5) so as to minimize dengue outbreak risk and achieve the SDM. It was worth noting that *Aedes* surveillance, control efficacy evaluation, and supervision were carried out during the process of SAM.

RESULTS

During 2016–2019, *Aedes* surveillance was carried out in approximately 436 counties and regions from 23 PLADs in China every year.

When comparing the BI among the Class I PLADs, similar seasonal fluctuations of *Aedes* larvae were observed in all PLADs from 2016–2019. In Yunnan, the BI exceeded 5 from the second half of June to the first half of October in 2016 and 2019. For Hainan, the BI exceeded 5 in all years and the BI were between 5 and 20 sporadically throughout the year. Concerning Fujian, the BI exceeded 5 from the first half of March to the second half of November and were higher than 10 from the second half of April to second half of September in 2017 and 2019. For Guangxi, the BI were higher than 5 from the second half of May to the first half of October in 2019. In Zhejiang, the BI exceeded 5 from the second half of April to the first half of November in all surveillance years.

However, all BI in Guangdong did not exceed 5 from 2016 to 2019. The risk indicated by BI surveillance was inconsistent with the actual dengue outbreak in Guangdong (Figure 1).

Excluding May and October in Shanghai and May, June, and October in Jiangsu, the BI in all Class II PLADs during the study months from 2016–2019 were higher than 5. Except Shanghai and Jiangsu, all other PLADs were at the risk of dengue outbreak or epidemic (Table 1).

As for the BI in Class III PLADs, the BI exceeded 5 in Hebei while it did not exceed 5 in Liaoning and Tianjin during the period of surveillance from 2016 to 2019. The BI exceeded 5 in most months in Shandong and Shaanxi and for a few months in Shanxi (Figure 2).

The MOI was another key index that was utilized by some PLADs for the surveillance of *Aedes* larvae. This indicator was more sensitive than BI in some PLADs, especially in Guangdong. The MOI exceeded 5 from the first half of May to the first half of October in Guangdong and from the second half of May to the second half of September in Guangxi for almost all study years (Figure 3).

For Guizhou, the MOI exceeded 5 from June to September in all studied years and exceeded 5 in May and October in 2016. In Hunan, the MOI exceeded 5 from June to September in most study years. Beijing, as a representative of Class III area, had a relatively high MOI in August and was at the risk level between dengue transmission to epidemic risk, especially from 2017 to 2019 (Table 2).

DISCUSSION

In this study, we focused on the findings of *Aedes* larval surveillance in China during 2016–2019. The findings are the basis of risk warning and strategic control of dengue.

In Zhejiang and Hainan, the BI exceeded the threshold of dengue transmission in nearly all surveillance months and the threshold of dengue outbreak in some surveillance months during 2016–2019. Dengue outbreaks occurred frequently in Zhejiang during recent years and in Hainan in 2019. High density of *Aedes* larvae may be one of the driving factors of dengue outbreak in these two PLADs during recent years. *Aedes* larval density in Fujian and Guangxi was also high and could be attributed to the increased incidence, frequent local outbreaks, and expansion of dengue distribution in PLADs during recent years (*8*).

With long border lines, large amount of cross-border population movement, and a suitable climate and ecological environment for *Aedes* mosquitoes, indigenous dengue has occurred frequently in Yunnan since 2013. Dengue has an external incubation period of usually 8 to 10 days and an internal incubation period of about 5 to 8 days. The fact was that sporadic dengue cases or dengue outbreaks often occurred in Yunnan from the first half of July to the first half of November. Therefore, the possible outbreak period of dengue as indicated by combining periods of high *Aedes* density plus incubation periods was basically consistent with the real periods of emergence of local sporadic cases or outbreak in Yunnan (*9*). As a result, the local government organized intense mosquito control efforts and had a lower average BI than other class I PLADs during 2016–2019.

The MOI was another core larval density index and seemed to be more suitable for dengue risk warnings in Guangdong. In recent years, we have observed dengue outbreaks in many cities of Guangdong with BI less than 5 during 2016–2019, but dengue has occurred continuously in Guangdong since 2014 (*10*). Single use of BI could not assess the risk of dengue comprehensively and objectively possibly due major cities with large floating populations decreasing the sensitivity of BI. Based on previous interviews with staffs of local CDCs, the difficulty of household entry in Guangdong may lead to low household access, which in turn decreased the sensitivity of BI surveillance for dengue risk assessment.

The other *Aedes* surveillance tools with similar catching mechanism but different configurations, such as CDC autocidal gravid ovitraps, larvitraps, Mosq-

FIGURE 1. Breteau index (BI) in Class I areas in China (2016–2019).

TABLE 1. Breteau index (BI) in class II areas in China (2016–2019).

Province	Month	BI				Risk range*
		2016	2017	2018	2019	
Shanghai	May	2.62	4.51	2.92	2.81	No risk
	June	4.95	5.65	6.01	3.93	No–Low risk
	July	6.18	7.58	7.32	6.38	Low risk
	August	5.49	7.76	7.12	4.97	No–Low risk
	September	4.66	6.79	6.09	3.93	No–Low risk
	October	3.23	4.96	2.47	2.45	No risk
Chongqing	May	6.25	5.99	7.44	5.78	Low risk
	June	11.10	9.45	12.30	9.23	Low–Medium risk
	July	10.34	12.33	11.64	10.68	Medium risk
	August	9.80	9.45	9.40	8.39	Low risk
	September	7.73	8.54	8.85	13.55	Low–Medium risk
	October	5.95	5.09	5.05	8.35	Low risk
Jiangsu	May	2.40	1.27	3.07	2.50	No risk
	June	4.86	3.43	3.45	2.92	No risk
	July	5.99	4.66	3.07	4.92	No–Low risk
	August	7.13	4.74	3.64	4.07	No–Low risk
	September	4.78	5.00	2.89	3.47	No–Low risk
	October	3.99	1.94	1.21	1.68	No risk
Anhui	May	3.82	5.11	7.48	4.75	No–Low risk
	June	9.06	8.31	11.27	7.59	Low–Medium risk
	July	14.60	14.99	14.24	12.06	Medium risk
	August	11.96	18.14	14.75	12.24	Medium risk
	September	9.57	16.69	11.67	11.69	Low–Medium risk
	October	5.70	6.85	6.63	5.00	Low risk
Jiangxi	May	14.10	0.95	17.50	15.38	No–Low risk
	June	23.60	15.90	13.56	14.34	Medium–High risk
	July	12.48	7.90	11.00	11.38	Low–Medium risk
	August	12.67	9.62	7.55	10.56	Low–Medium risk
	September	8.76	8.89	8.00	7.69	Low risk
	October	15.33	4.63	6.70	2.86	No–Medium risk
Henan	May	10.10	14.70	10.50	4.69	No–Medium risk
	June	21.39	17.36	16.06	11.57	Medium–High risk
	July	31.88	26.22	24.90	22.92	High risk
	August	32.40	31.91	23.01	26.38	High risk
	September	32.07	23.62	13.49	18.91	Medium–High risk
	October	14.41	13.09	9.50	9.68	Low–Medium risk
Hubei	May	10.90	7.11	7.06	6.21	Low–Medium risk
	June	13.42	10.83	7.83	8.08	Low–Medium risk
	July	19.83	13.54	8.22	8.03	Low–Medium risk
	August	13.76	9.85	5.88	10.22	Low–Medium risk
	September	8.64	17.98	7.54	3.99	No–Medium risk
	October	7.22	5.87	3.53	7.14	No–Low risk

TABLE 1. (Continued)

Province	Month	BI				Risk range*
		2016	2017	2018	2019	
Hunan	May	17.90	6.90	13.93	12.60	Low–Medium risk
	June	17.90	31.20	13.83	26.47	Medium–High risk
	July	9.65	12.20	13.09	26.53	Medium–High risk
	August	10.95	4.14	13.23	16.48	No–Medium risk
	September	10.95	12.61	11.53	13.91	Medium risk
	October	3.44	5.55	9.78	4.98	No–Low risk
Sichuan	May	4.90	10.15	12.24	9.14	No–Medium risk
	June	7.60	15.39	11.95	12.89	Low–Medium risk
	July	8.33	18.23	15.96	28.31	Low–High risk
	August	13.36	12.62	14.02	11.64	Medium risk
	September	7.56	6.87	7.75	11.48	Low–Medium risk
	October	8.98	3.26	3.78	8.57	No–Low risk

* No risk (BI<5): dengue transmission negated; Low risk (5≤BI<10): sporadic dengue occurrence; Medium risk (10≤BI<20): dengue outbreak risk; High risk (BI≥20): dengue epidemic risk.

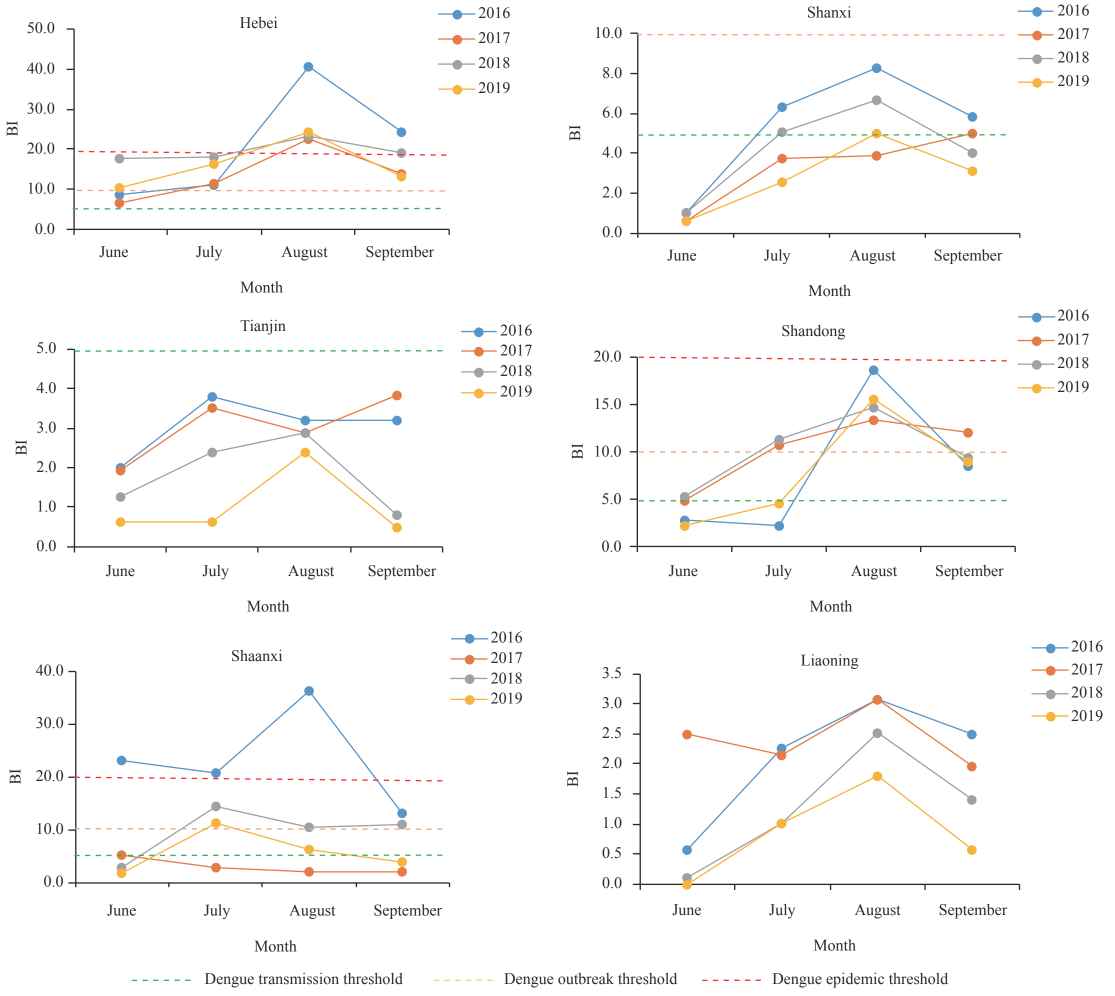

FIGURE 2. BI of Class III areas in China (2016–2019). BI=breteau index; MOI=mosq-ovitrap index.

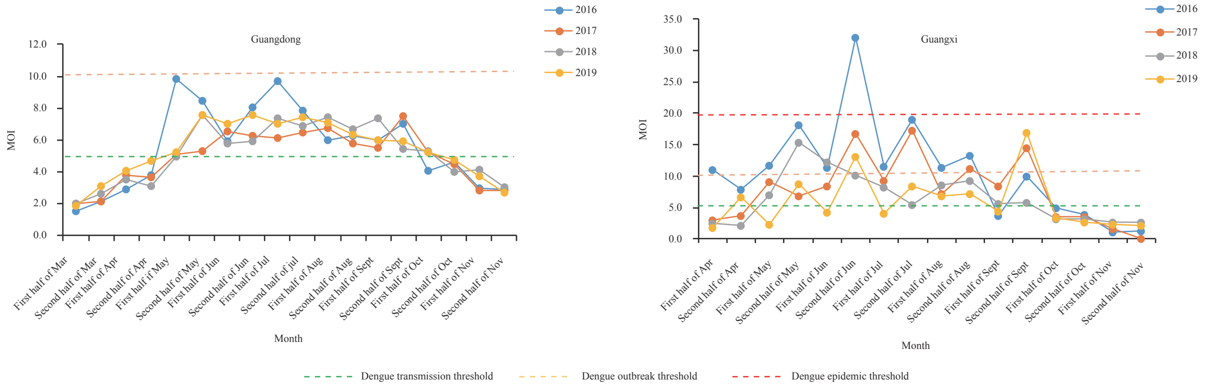

FIGURE 3. MOI of Guangdong and Guangxi in Class I areas of China (2016–2019). BI=breteau index; MOI=mosq-ovitrap index.

TABLE 2. Mosq-ovitrap index (MOI) in class II and III areas in China (2016–2019).

Class	Province	Month	MOI				Risk level*
			2016	2017	2018	2019	
II	Guizhou	May	5.29	4.61	4.71	4.13	No–Low risk
		June	7.81	7.59	6.73	5.45	Low risk
		July	8.87	7.43	9.28	8.11	Low risk
		August	11.03	5.75	9.01	10.08	Low–Medium risk
		September	9.05	5.42	5.84	7.86	Low risk
		October	5.74	4.09	3.96	4.34	No–Low risk
	Hunan	May	3.12	1.35	1.44	0.78	No
		June	9.83	3.77	2.28	5.11	No–Low risk
		July	8.89	5.59	5.18	6.04	Low risk
		August	6.49	5.18	3.40	6.06	No–Low risk
		September	6.49	6.72	3.81	4.49	No–Low risk
		October	3.52	3.76	0.86	1.58	No
III	Beijing	June	3.74	2.34	1.27	1.06	No
		July	3.57	7.45	3.99	3.05	No
		August	4.87	10.76	8.71	9.30	No–Medium risk
		September	5.87	3.69	4.86	1.16	No–Low risk

* No risk (MOI<5), dengue transmission negated; Low risk (5≤MOI<10), sporadic dengue occurrence; Medium risk (10≤MOI<20), dengue outbreak risk; High risk (MOI≥20), dengue epidemic risk.

ovitraps (China), etc. have been implemented widely around the world (*11*). In this study, Mosq-ovitrap was utilized and the MOI was calculated accordingly. The risk as indicated by average MOI in Guangdong reached dengue transmission risk from the first half of May to the first half of October for almost all studied years. One of the advantages of MOI surveillance is that the trapping does not have to be conducted in households. In the future, the Mosq-ovitrap method should also be carried out in some PLADs with potential risk of dengue transmission or outbreak despite low BI to augment the deficiencies of BI surveillance.

This study demonstrated that the *Aedes* larval density was always low in Shanghai and Jiangsu, and this may be the main reason why there was no local outbreak of dengue in these two PLADs during recent years. However, Chongqing and Jiangxi witnessed the first outbreak of indigenous dengue in 2019 and these two PLADs had high BI in the same year. And BI of Henan and Anhui were also high and experienced local dengue transmission or outbreaks during recent years.

As for BI surveillance in Class III PLADs, we need to emphasize the transmission risk of dengue in Hebei due to the high density of *Aedes* larvae during recent years. Furthermore, the BI exceeded 5 in most months in Shandong, a PLAD with two recent dengue outbreaks. In Beijing, the MOI in August reached dengue transmission risk level during 2017–2019. Once an imported dengue case occurs, the possibility of local dengue transmission or outbreak appears.

Due to the deficiencies in the local capabilities of *Aedes* surveillance and availability of surveillance data, this study calculated the overall average density of *Aedes* species rather than calculating the density of *Ae. aegypti* and *Ae. albopictus* separately. In addition, a dengue outbreak is driven by multidimensional factors and there are a certain limitations to using a single vector index for dengue risk assessment. Therefore, further studies are warranted to distinguish *Ae. aegypti* from *Ae. albopictus* for precise surveillance of *Aedes* and for carrying out dengue risk warnings using multidimensional factors to provide scientific basis for SDM in the future.

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REFERENCES

1. Castro MC, Wilson ME, Bloom DE. Disease and economic burdens of dengue. Lancet Infect Dis 2017;17(3):e70 – 8. https://www.ncbi.nlm.nih.gov/pubmed/28185869.
2. Liu BY, Gao X, Ma J, Jiao ZH, Xiao JH, Hayat MA, et al. Modeling the present and future distribution of arbovirus vectors *Aedes aegypti* and *Aedes albopictus* under climate change scenarios in Mainland China. Sci Total Environ 2019;664:203 – 14. http://www.ncbi.nlm.nih.gov/pubmed/30743113.
3. Li YJ, Kamara F, Zhou GF, Puthiyakunnon S, Li CY, Liu YX, et al. Urbanization increases *Aedes albopictus* larval habitats and accelerates mosquito development and survivorship. PLoS Negl Trop Dis 2014;8(11):e3301. http://www.ncbi.nlm.nih.gov/pubmed/25393814.
4. Davis CE. Globalization, climate change, and human health. N Engl J Med 2013;369(1):94 – 5. http://www.ncbi.nlm.nih.gov/pubmed/23822792.
5. Liu PB, Lu L, Jiang JY, Guo YH, Yang MD, Liu QY. The expanding pattern of *Aedes aegypti* in southern Yunnan, China: insights from microsatellite and mitochondrial DNA markers. Parasit Vectors 2019;12(1):561. https://www.ncbi.nlm.nih.gov/pubmed/31775906.
6. Fan JC, Liu QY. Potential impacts of climate change on dengue fever distribution using RCP scenarios in China. Adv Climate Change Res 2019;10(1):1 – 8. https://dx.doi.org/10.1016/j.accre.2019.03.006.
7. Liu QY. Challenge to vector control and sustainable vector management strategy. Chin J Epidemiol 2012;33(1):1 – 8. https://www.ncbi.nlm.nih.gov/pubmed/22575100. (In Chinese).
8. Wang JZ, You LB, Kan NP, Lin Q, Weng YW, Zheng KC. Frequent import and multiple sources of dengue fever have changed the epidemic situation of the disease in Fujian Province, China. Biomed Environ Sci 2020;33(2):123 – 32. https://www.ncbi.nlm.nih.gov/pubmed/32131959.
9. Liu KK, Hou X, Wang YG, Sun JM, Xiao JP, Li RY, et al. The driver of dengue fever incidence in two high-risk areas of China: a comparative study. Sci Rep 2019;9(1):19510. https://www.ncbi.nlm.nih.gov/pubmed/31862993.
10. Chen B, Liu QY. Dengue fever in China. Lancet 2015;385(9978):1621 – 2. http://www.ncbi.nlm.nih.gov/pubmed/25943817.
11. Hasty JM, Felix GE, Amador M, Barrera R, Santiago GS, Nakasone L, et al. Entomological investigation detects dengue virus type 1 in *Aedes* (*Stegomyia*) *albopictus* (Skuse) during the 2015–16 outbreak in Hawaii. Am J Trop Med Hyg 2020;102(4):869 – 75. https://www.ncbi.nlm.nih.gov/pubmed/32043443.