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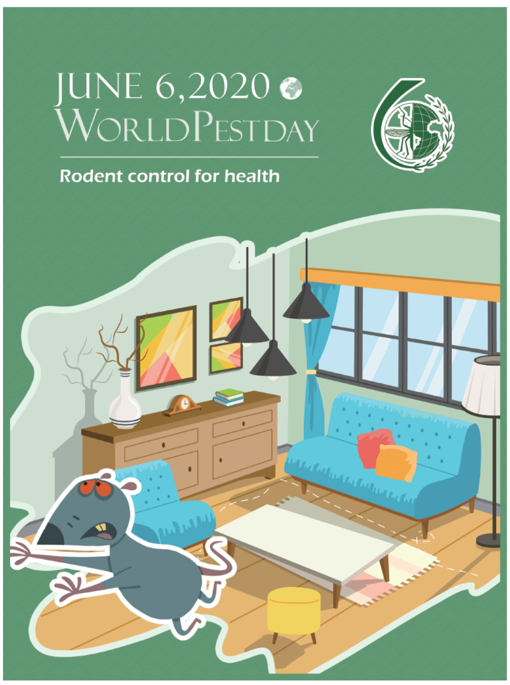

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Cover Image: The Poster for the 4th World Pest Day, designed by Yanyun Li, Beijing Angrui Culture Co., Ltd.

Announcements

World Pest Day: Not for Pests, But for People

Jianguo Xu#

World Pest Day was inaugurated by the Chinese Pest Control Association and several organizations such as the Federation of Asian and Oceania Pest Managers Associations, the National Pest Management Association of US, Confederation of European Pest Management Associations, World Health Organization (WHO) Collaborating Centre for Vector Surveillance and Management, and State Key Laboratory of Infectious Disease Prevention and Control (China CDC). It was endorsed by 42 academicians from the Chinese Academy of Science and Chinese Academy of Engineering, as well as 21 Members of the National Political Consultative Committee of China. June 6 is reserved annually to raise awareness among the public, government, and media about the important role that the pest control industry plays in protecting health, food, property and the environment from pest threats.

World Pest Day is for the people, not for the pests (*1*). Globally, more and more vector-borne pathogens have recently emerged (*2*). The diseases transmitted by mosquitoes, ticks, and rodents have been extensively reported, such as human granulocytic anaplasmosis, dengue (*3*), new bunia virus, and Jingmen tick-borne virus. More than 5 billion people worldwide are at risk of one or more vector-borne diseases, and over 0.7 million people die annually from these diseases.

Pests are an important factor of reduction in food production and pollution (*4*). Therefore, the theme of World Pest Day 2018 was "pest control for food safety". Conservative estimations suggest that pests are responsible for an 8%–10% loss of grain stored by farmers and households in China, which may be as much as 1.5–6 million tons.

With the acceleration of globalization, pests are increasingly capable of crossing borders between countries using modern means of transportation. This can have consequences for human and animal health as well as for food safety.

Climate changes, especially the increase in temperature, mean that pests can live longer or no longer die at the same rate due to milder winters (*5*). In combination with globalization, this creates a risk for mosquitoes to spread across countries and transmit dangerous diseases. Increased urbanization also increases the potential for nuisances from pests such as rodents.

If we want to achieve the grand goal of Healthy China and Healthy World, we must control harmful pests and improve the quality of life (*6*). We want to keep mosquitoes, rodents, and other pests away from our home and our working and leisure environments at the very least.

Science and technology are eagerly needed to promote pest control practice. Although increasing numbers of advanced products and equipment appear every year, these advances are insufficient and need to be increased.

We need support from governments, academic organizations, the public, media, and industries to spread the concept of scientific pest control, to enhance the professional respect of pest control practitioners, and to call on people to pay attention to pest control activities (*6*).

Rodents can transmit a variety of diseases and have caused three plague pandemics in history. The year of 2020 is the year of rat in Chinese Lunar Calendar. The theme of World Pest Day 2020 is rodent control for health. We hope that we can take action to jointly control damage caused by rodents and to prevent rodent-borne diseases and protect human health and well-being.

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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.

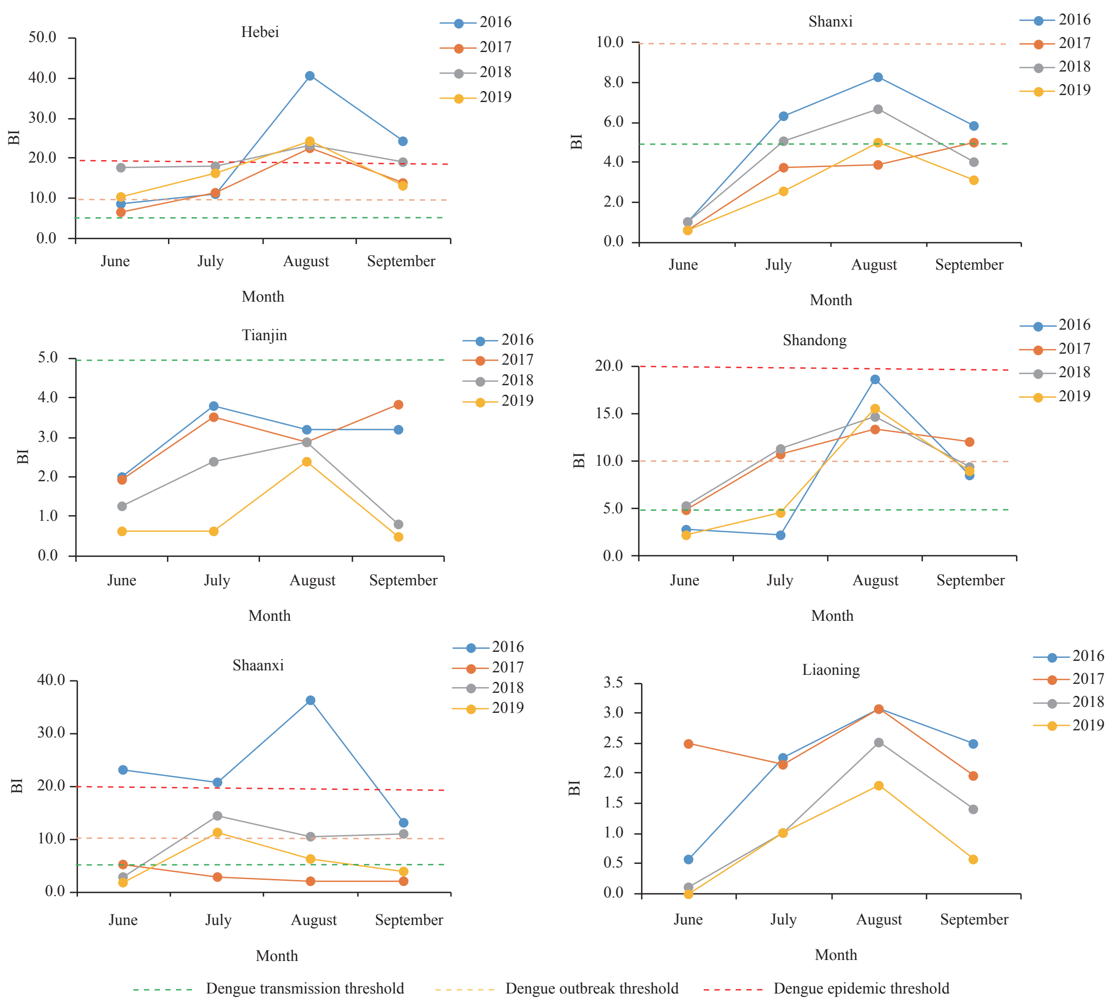

FIGURE 2. BI of Class III areas in China (2016–2019). BI=breteau index; MOI=mosq-ovitrap index.

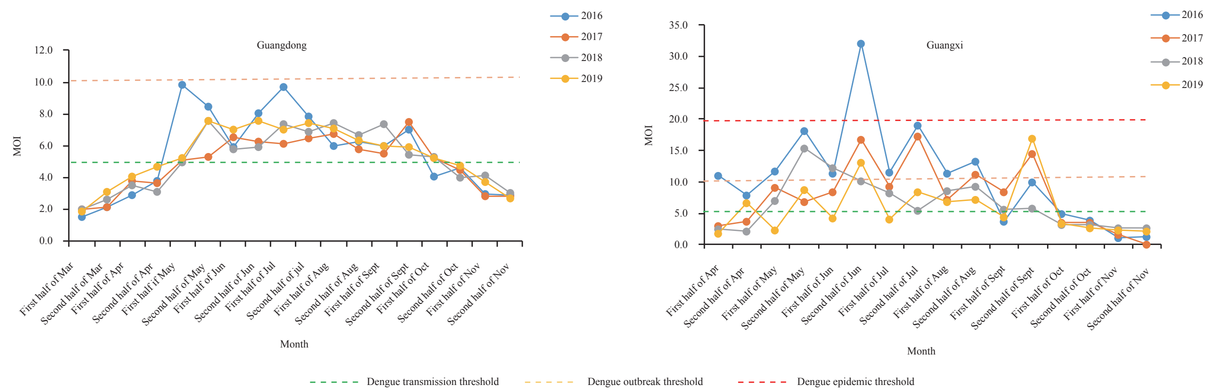

FIGURE 3. MOI of Guangdong and Guangxi in Class I areas of China (2016–2019). BI=breteau index; MOI=mosq-ovitrap index.

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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Commentary

Sustainable Pest Management for Health and Well-Being

Qiyong Liu[1,#]

Pests can not only cause nuisances and allergic reactions and transmit a range of diseases, but they can also pose serious threat to other aspects of life such as the environment, food, agriculture, crops, etc. Over time, the pest control industry has made great progress but has encountered some new challenges and gaps.

To adapt to global changes effectively, pest management strategies are changing constantly. The concept has transitioned from integrated pest management (IPM) to sustainable pest management (SPM) to provide the optimal solution. China, as the world's largest developing country, has continuously contributed innovative ideas to the pest management industry to promote sustainable development of pest management globally. This paper focuses on pests and their adverse impacts, especially in the health field, the challenges and gaps in pest management, the conceptual transition in pest management, and future perspectives.

Pests and Their Adverse Impacts

Pests are organisms that damage human life, production, and even survival. They can cause significant losses in lives and property and also great loss in other fields such as agriculture, food, environment, and ultimately have a negative impact on people's health and well-being. Pests can be roughly divided into seven categories based on their adverse impacts (Table 1).

On the basis of the World Health Organization's (WHO) report, 80% of the world's population is at risk of one or more vector-borne diseases (VBDs), and 17% of the global burden of communicable diseases and over 700,000 deaths are due to VBDs. Malaria causes an estimated 219 million cases globally and results in more than 400,000 deaths every year. More than 3.9 billion people in over 129 countries are at risk of contracting dengue with an estimated 40,000 deaths every year. More over, there are other VBDs including mosquito-borne diseases such as Chikungunya fever, Zika virus infection, yellow fever, West Nile fever, and Japanese encephalitis as well as tick-borne encephalitis. Of note, some VBDs such as Chagas disease (transmitted by triatomine bugs), leishmaniasis (sandflies) and schistosomiasis (snails) affect hundreds of millions of people worldwide.

In China, vectors transmit 10 notifiable VBDs in 3 categories [category A: plague; category B: hemorrhagic fever with renal syndrome (HFRS), epidemic encephalitis B, dengue, leptospirosis, schistosomiasis, and malaria; and category C: epidemic and endemic typhus, visceral leishmaniasis (kala-azar), and filariasis], 10 non-notifiable and common VBDs (tick-borne forest encephalitis), Xinjiang hemorrhagic fever, Lyme disease, bartonellosis, Zika virus infection, human ehrlichiosis, anaplasmosis, Tsutsugamushi disease, Chikungunya, severe fever with thrombocytopenia syndrome (SFTS), and many other kinds of NTDs or emerging VBDs.

For the adverse impacts of pests in other fields, the Food and Agriculture Organization of the United Nations (FAO) reports that up to 40% of food crops are destroyed by plant diseases and pests every year. This has resulted in food shortages for millions of people and has caused negative impacts on the main sources of income for poor rural communities by resulting in production and trade losses. In recent years, China's grain production has been reduced by about 40 million tons annually due to pests, which can supply the annual grain consumption of about 80 million people or about 5.3% of China's total population.

Pest can also cause serious losses in animal husbandry. Through biting, *Tabanus* horseflies can directly reduce the body weight of cattle by 0.1–1 kg per day and lead to the reductions in production resulting in huge economic losses. Ticks can spread babesiosis, and theileriosis (East Coast feeder) among livestock causing significant economic losses. In 1999, the animal husbandry losses caused by ticks in Tanzania reached 55 million US dollars.

Based on the FAO's report in 2010, nearly 40 million hectares of forest were affected by plant diseases and insect pests every year. In recent years, the annual average occurrence area of forest pests in China is 120 thousand square kilometers, and the annual

TABLE 1. Pests and their adverse effects.

No	Category of pest	Representative species	Adverse effects	Sources
1	Disease vectors	Mosquitoes, sandflies, triatomine bugs, ticks, fleas, flies (various species), aquatic snails, lice, mites, midges, rodent, etc.	· Globally: · 80% of the world's population is at risk of one or more vector-borne diseases (VBDs). · 17% of the global burden of communicable diseases is due to VBDs. · Over 700,000 deaths are caused by VBDs annually. · China: · 10 notifiable VBDs, 10 non-notifiable and common VBDs, and several other kinds of other NTDs or emerging VBDs. · In 2019, 13 indigenous dengue transmission provincial-level administrative divisions (PLADs), and more than 0.9 billion people are at the risk of dengue. · Imported malaria from Africa and Southeast Asia pose a challenge to the elimination of malaria in China by 2020. · Adult epidemic encephalitis B outbreak in the provinces of Northwest China in recent years.	[*1*] Global vector control response (GVCR) 2017–2030. [*2*] Qiyong Liu, 2020.
2	Exotic invasive pests	*Solenopsis invicta* Buren, *Bursaphelenchus xylophilus*, ragweed, water hyacinth, etc.	· *Solenopsis invicta* Buren: · Globally: · One of the 100 most destructive invasive pests in the world, this pest poses a great threat to biodiversity protection and agricultural production. · As of 2012, more than 100 million acres of land in 12 south states of the United States had been infested, with an estimated annual economic loss of more than 5 billion USD and over $750 million in agricultural losses. · China: · In 2013, detected in 169 counties (cities and districts) of 7 PLADs. · Bursaphelenchus xylophilus: · Globally: · Occurs in Japan, Republic of Korea, the United States, Canada, Mexico, Portugal, China, and other countries and causes significant loss. · China: · After an invasion to Hong Kong in the 1980s, the *Pinus massoniana* was almost destroyed by this pest. · The economic losses caused by *Bursaphelenchus xylophilus* disease in Anhui and Zhejiang provinces are up to 70.18–98.26 million USD.	[*1*] http://blog.sciencenet.cn/blog-990233-763021.html [*2*] https://baike.baidu.com
3	Architecture and building material pests	Termites, wood-boring beetles, *Monochamus*, *Sinoxylon*, *Lyctus*, *Trogoderma*, etc.	· Termites: · Globally: · More than 3,000 species in the world and known as "silent destroyers" because of their ability to chew through wood, flooring, and even wallpaper undetected. · The direct economic loss caused by termites reach up to tens of billions USD every year. · China: · More than 70 species that can damage architecture and housing materials. · The economic loss caused by termites to housing construction is close to $1.0 billion every year.	[*1*] https://www.pestworld.org/pest-guide/termites/ [*2*] https://baike.baidu.com

TABLE 1. (Continued)

No	Category of pest	Representative species	Adverse effects	Sources
4	Warehouse pests	Flour beetles, grain borers, corn weevil, rice weevil, corn beetle, wheat moth, *Tribolium castaneum*, etc.	· Globally: · More than 300 species, causing direct weight loss, quality loss and mildew. · China: · More than 50 species, causing about 8%–10% of the total reserves in grain, beans and oil-bearing crops by warehouse pests. · Corn weevil ranking first in warehouse pests in China.	[1] Jianguo Xu, 2018 [2] https://baike.baidu.com
5	Textile pests	Carpet beetles, moth, etc.	· Globally and China: · Causing huge losses in the production and storage of commercial fabrics and clothing.	[1] https://wenku.baidu.com/view/8d869511cbaedd3383c4bb4cf7ec4afe04a1b122.html [2] https://www.byepest.com/pest_wiki_details/13
6	Agricultural and forestry pests	Locusts, aphids, etc.	· Globally: · Agricultural pests: · Up to 40% of food crops destroyed by plant diseases and pests every year. · Locusts: · About 300 species are harmful to agriculture, forestry, and animal husbandry. · The annual area of locust disasters amounting 46.8 million square kilometers, and one eighth of the world's population is affected by locust disasters. · The most serious locust is *Schistocerca grigaria*, with a maximum diffusion area of 28 million square kilometers, including whole territories and partial areas of 66 countries, accounting for about 20% of the world's land area and more than 10% of the world's population. · Aphiods · One of the most destructive pests on earth. · About 250 species harmful to agriculture, forestry and horticulture. · Forest pests: · The area of forest affected by pests every year reaching 34 million hectares, accounting for 1.6% of the forest area of 94 reporting countries. · China: · Agricultural pest: · Locusts: · The severest locust disaster in a year in China causing nearly 0.20 million square kilometers crop loss, with an average of 0.10 million square kilometers and an average annual loss of 0.25 billion USD, posing a serious threat to food production and ecological security of grassland areas. · In 2008, Heilongjiang suffered from *Loxostege stieticatis* damage, with a disaster area of more than 2.867 million hectares. · In 2004, Jiangxi suffered rice diseases and insect pests, with a total loss of 1.7 billion kg of grain. · Forest pests · The annual average occurrence area of forest pests in China amounted to 120 thousand square kilometers, and the annual average economic loss reached 15.46 billion USD.	[1] FAO, 2010 [2] National Forestry and Grassland Administration (NFGA), China, 2019 [3] https://baike.baidu.com [4] Jianguo Xu, 2018
7	Animal husbandry pests	Ticks, tabanus, etc.	· Globally: · Tick-borne diseases (TBD) constraining cattle production and improvement in Tanzania, and the total annual national loss due TBD estimated to be 364 million USD, including an estimated mortality of 1.3 million cattle.	[1] Fredrick M Kivaria, 2006 [2] Busin V, 2018

average economic loss is 15.45 billion USD.

Challenges and Gaps Towards Pest Management

In recent years, climate and environmental change, globalization, urbanization, insecticide resistance, human behavior change, etc., pose new challenges for pest management causing unfavorable effects to the health and well-being of humans.

Changes in vector distribution are being driven by climatic and environmental changes. Globally, the areas and human populations at risk for dengue have recently been increasing significantly due to the spreading of *Aedes albopictus* and *Ae. aegypti* resulting from climate change. In China, more than 0.9 billion people currently reside in the risk area of dengue (*1*), and the risk area and risk populations will increase significantly in the future (*2*). Due to climate change, mosquitoes in *Culex pipiens* complex have established its population in Lhasa, Tibet (*3*). With the changing of the environment, human granulocytic anaplasmosis, a tick-borne disease, was identified in China before 2006 (*4*). In 2019, the market scale of China's health insecticides reached more than 2.10 billion USD and will continue to grow at a rate of more than 8%. In the future, insecticide resistance will become a more and more serious problem. Outside of China, an unprecedented change in the status of VBDs in Europe has occurred in the early 21st century due to increased globalization (*5*).

In addition, there are still many deficiencies and gaps concerning capacity building such as insufficient ability for the fast identification of pests, lack of high-tech pest surveillance and control tools, lack of self-protection awareness against pests, etc.

Transition of Pest Control Strategy: from IPM to SPM

IPM is a science-based, strategic approach for managing insects, rodents, or other vectors. It uses a variety of pest management techniques that focus on pest prevention, pest reduction (*6*), and the elimination of conditions that lead to pest infestations. Integrated vector management (IVM) is a key component of IPM (*7*). Though IPM is a comprehensive approach to pest management, its noticeable deficiencies are its lack of planning and systematization towards pest management, more involvement in the technicalities of the method, and being time and energy consuming. Therefore, an innovative pest management concept is urgently needed to guide the pest management practice.

SPM was first proposed by Professor Qiyong Liu in the Pest Management Industry Global Summit, which took place on May 25–27, in Barcelona, Spain in 2010. SPM is designed to meet society's current and future needs for the protection of human health and the environment for the production of food, feed, and fiber and for the use of natural resources. SPM stresses on systematic and sustainable pest management through pest surveillance, risk assessment and alert, control planning, good pest control practice, monitoring and evaluation. It combines a range of pest management practices, including judicious use of pesticides to ensure that our natural resources are utilized efficiently and conserved for future generations. It also addresses the economic viability of available and new pest control products and practices and the planning and systematic nature of pest management. In recent years, VBDs posed great challenges to existing vector control strategies and measures, and mitigation of VBDs will increase economic prosperity by reducing poverty, decreasing productivity losses due to death and disability, and reducing inequality in health and economic outcomes.

Take *Aedes* control for dengue management in China for example. The process of dengue control under the guidance of SPM (with SVM as the core) is as follows (*8*): first, carry out *Aedes* surveillance in a timely and effective fashion; second, conduct a feasibility risk assessment and control planning of *Aedes* and dengue; and third, choose environmentally friendly techniques and measures comprehensively and in order to implement surveillance-based *Aedes* control and management consistently. During the process, conduct coordinated activities with multisectoral collaboration and public participation, and suppress the *Aedes* density below the threshold of dengue transmission (Breteau index or Mos-ovitrap index<5) (*9*). This method promoted the transition from reactive outbreak response to proactive outbreak risk reduction of *Aedes*-borne diseases in China.

As a core component of SPM, SVM was cited by the "Guidelines for dengue prevention and control (2014)" from the China CDC and "Western Pacific Regional Action Plan for Dengue Prevention and Control (2016)" from the WHO. Other WHO guidelines also reference SVM including "The global strategy for dengue prevention and control (2012–2020)" and "Global Vector Control Response 2017–2030" (*10*), etc.

SPM for Health and Well-Being

In the future, we will confront challenges and gaps continuously, and some new challenges may also emerge (*11*). Pests will become increasingly harmful and will adversely affect public health and well-being. Therefore, current challenges need to be addressed, existing deficiencies must be made up, and SPM should be carried out. Global and regional cooperation, multisectoral joint action and multi-disciplinary integration should be strengthened, and the participation of the whole society should be advocated to actualize the sustainable control of pests and the promotion human health and well-being.

In the long run, SPM is likely to be beneficial for the reduction of diseases and poverty, protection of the environment, elimination of hunger, promotion of economic development, and ultimately contributing to human health and well-being and the achievement of sustainable development goals (SDGs).

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Recollection

Thoughts on 2020 World Pest Day

Xiaoyun Huang[1]

In view of the "Big Harms" that may be attributable to the "Small Pests" around us, the launch ceremony of "World Pest Day" was held at Beijing Hotel on June 6, 2017. The original goals and development processes of World Pest Day are to gain well-deserved respect for the global pest control industry and to open up a new way of thinking to facilitate industry's public-facing platform and ultimately to achieve positive changes in public health. Since the establishment of World Pest Day, different countries and regions have carried out various activities based on specific needs of the countries or regions. This paper also seeks to appeal to the general public about the great importance of pest control industry on public health and to emphasize the key role pest control industry plays on the prevention and control of infectious diseases, especially during the period of the coronavirus disease 2019 (COVID-19) pandemic in 2020.

Preparation, Gestation, Planning, Action and Result of World Pest Day (2015–2017): Based on Global Vector Control Response 2017–2030, 80% of the world's population is at risk of one or more vector-borne diseases (VBDs) and over 700,000 deaths are caused by VBDs annually. This poses a clear and present danger to public health.

In order to raise the public's awareness about the prevention and control of VBDs, I first proposed in May 2015 the idea of designating June 6 as "World Pest Day". With the strong support and guidance of Dr. Jianguo Xu, President for the Chinese Pest Control Association (CPCA), and the joint support of Qiyong Liu, the head of the World Health Organization (WHO) Collaborating Centre for Vector Surveillance and Management (WHOCCVSM), in 2015 and 2016, the CPCA began to carry out research on various internationally-recognized awareness days, drafted the World Pest Day Proposal, and sent staff to various international conferences to promote the initiative and to solicit signatures from international colleagues. Nearly 10,000 representatives from more than 30 national associations around the world and the WHO became signatories to support "World Pest Day" including Nobel laureate Tu Youyou who signed on to lend her support. With the efforts of Dr. Xu Jianguo, who is also a member of academicians of the Chinese Academy of Engineering, World Pest Day received strong support from Mr. Zhong Nanshan and other 41 Chinese academicians as well as 21 members of the National Committee of the Chinese People's Political Consultative Conference. These efforts paved the way for the official launch of World Pest Day (*1*).

On June 6, 2017, more than 300 delegates, including pest control industry leaders, scientific research elites, celebrities, and media members from more than 20 countries and regions on 5 continents, witnessed the birth of "World Pest Day" (*2*). Led by the CPCA in collaboration with the WHOCCVSM, FAOPMA, National Pest Management Association (NPMA) in the United States, Confederation of European Pest Control Associations (CEPA) and other co-sponsors, "World Pest Day" as born (*3*). More than 200 Chinese and foreign media members participated in the event. Associations and other organizations from the United States, Australia, India, Britain, France, Spain, Italy, Germany, Hungary, Peru, South Africa, Mexico, and other countries and regions have held press conferences and events (*4*).

Theme, Purpose and Activities of World Pest Day (2018–2019): Pests pose a serious threat to the food security of China and the world. China's total annual grain production's loss caused by pests which accounts for nearly 30% of the total output loss. Each year, food losses caused by pest damage amount to 1.5 to 6 million tons, and direct economic losses exceed 2 billion yuan. From 2006 to 2015, pests that are commonly found in grain storage facilities such as *Sitophilus oryzae*, *Tribolium castaneum*, *Rhizopertha dominica*, and *Tineidae* caused losses of 301,900 tons of soybeans, 3.336 million tons of wheat, and 4.988 million tons of rice in China.

On June 6, 2018, the theme of the World Pest Day was "Controlling Pests and Ensuring Food Safety." The main venue of World Pest Day was in Lisbon, Portugal. Representatives from more than 80 countries participated in the event. Dr. Qiyong Liu, the chief scientist for vector control of China CDC and the head of the WHOCCVSM, delivered a keynote speech titled "Pest Control for Public Health and Food Safety". Also on behalf of China, I was awarded the "Global Industry Ambassador" by NPMA and the first ever "Outstanding Contribution Award" awarded by FAOPMA.

Additionally, events in Asia, Oceania, Europe, America, and Africa took place on the same day. With the theme "Controlling Pests and Ensuring Food Safety", the State Key Laboratory of Infectious Disease Prevention and Control (SKLID) opened its lab to the general public in Beijing, China. Dr. Jianguo Xu gave a keynote speech on "Controlling Pests and Ensuring Food Safety". There were expert forums, pest prevention and control science education sessions, pest control live demonstrations, and interactive sessions with the media. A series of key laboratory opening activities were organized, such as the popular science exhibition on the subject of pest ecology, its harms, identification of pests, exhibition of history of infectious diseases control, and the public viewing of laboratory experiments. Education sessions were held with easy to understand analysis about the damages caused by pests from the cultivation and growing of raw food materials, to harvesting and storage, to transportation, processing, and consumption. Comprehensive prevention and control measures on effective pest control were also presented. During the week of June 6, various events took place in more than 30 cities, including Beijing, Shanghai, Tianjin, Chengdu and Chongqing in China. More than 80 Chinese media members reported the event, and World Pest Day posters were displayed anywhere around a number of cities. Each community posted information on World Pest Day on bulletin boards with more than 18 million people viewing the information nationwide every day (*5*).

On June 6, 2019, the theme of World Pest Day was "Pest Control for Healthy Communities". Communities are the fabric of society, and building healthy communities is an important part of achieving a healthy China. With the increasing level of people's awareness on public health, pest control in our community has become one of the vital aspects of building a healthy community. "2019 World Pest Day Live Meeting" with the theme "Pest Control for Healthy Communities" was jointly hosted by the CPCA and Tianjin Pest Control Association in Tianjin Municipality, China (*6*). Experts were invited to give scientific lectures on "Pest Control for Healthy Communities"; the public announcement cartoon short film "Fighting against Mosquito" also premiered; expert consultation on pest control technology, live demonstration of pest control project, interactive media sessions were carried out; a series of activities were organized such as the scientific exhibition on pest control and various forms of science education about community pest control. Around June 6, 2019, more than 40 cities in China including Shanghai, Guangzhou, Shenzhen, Chongqing, Chengdu, Hefei, Nanjing, and Fuzhou, organized World Pest Day-related activities for the general public, which was widely reported by more than 120 Chinese media outlets (*7*).

Theme, Prospect and Suggestions of the 2020 World Pest Day: Rodent-related threats in China are particularly destructive, causing annual agricultural losses of about 15 million tons and economic losses of tens of billions RMB. At the same time, rodent-borne diseases also pose a serious threat to public health. Among the dozens of rodent-borne diseases, plague, hemorrhagic fever with renal syndrome (HFRS), and leptospirosis are the most threatening ones. Among them, HFRS is the most common disease with an annual case count of more than 100,000 in China in the past, but had been limited to between thousands of cases to tens of thousands of cases in recent years due to effective rodent control. Presently, with rapid economic development, changes in ecology, climate, and land use patterns, as well as the development of tourism, the number and density of rodents are gradually increasing, which has exacerbated the high incidence of emerging rodent-borne diseases. It not only poses a serious threat to people's health but also has a potential negative impact on social stability and economic development.

To this end, the theme of World Pest Day 2020 in China will be Rodent Control for Health. In 2020, the sudden outbreak of COVID-19 disrupted the daily routine of the entire world, which has had a serious impact on our work, lives, and the economy. In the global fight against the pandemic, the pest control industry from all countries and regions are also facing severe impacts and challenges. Many restaurants, hotels, factories, etc. have chosen to forego pest control services for economic reasons, which has led to the suspension of routine pest control activities and could increase the outbreak risks of VBDs such as dengue and plague. The COVID-19 pandemic will inevitably exacerbate public health crises in many countries and strain public health resources. As a former president of the FAOPMA, I appeal to the public health authorities of all countries and regions, pest control professionals and general public: It is time to recognize the enormous contribution of pest control industry made to public health and to understand the key role pest control industry plays in the prevention and control of infectious diseases.

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