BioScience Trends. 2025; 19(4):404-409. *www.biosciencetrends.com*

Review

DOI: 10.5582/bst.2025.01239

Chikungunya's global rebound and Asia's growing vulnerability: Implications for integrated vector control and pandemic preparedness

Jing Ni[1,§], Zhifang Li[2,§], Xiaowei Hu[3,§], Hui Zhou[4], Zhenyu Gong[5,*]

[1] School of Public Health, Hangzhou Medical College, Hangzhou, China;
[2] Tonglu Centre for Disease Control and Prevention, Hangzhou, China;
[3] Hangzhou West Lake District Center for Disease Control and Prevention, Hangzhou, China;
[4] Longyou Centre for Disease Control and Prevention, Quzhou, China;
[5] Department of Communicable Disease Control and Prevention, Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou, China.

SUMMARY: Chikungunya fever is a mosquito-borne disease caused by an RNA virus of the Alphavirus genus and is characterized by fever and severe joint pain. The disease is primarily transmitted by Aedes aegypti and Ae. albopictus mosquitoes. Since its re-emergence in 2005, chikungunya has spread extensively, affecting more than 2.8 billion people across 119 countries worldwide. This article reviews the global epidemiological features of chikungunya, with a focus on its transmission dynamics, the characteristics of the virus and its vectors, as well as the influence of ecological and climatic factors. The article also discusses public health response measures, including the Wolbachia strategy, vaccine development, and integrated vector management. Despite China being a non-epidemic area, imported cases have led to localized outbreaks, prompting the implementation of the 'Four Pests-free Village' initiative to reduce mosquito density and improve public health. Notably, as of July 31, 2025, Guangdong Province in China has reported over 5,158 chikungunya cases and has initiated a Level 3 emergency response in the City of Foshan. In the face of global challenges such as climate change and the spread of invasive species, establishing a normalized rapid response system and enhancing monitoring, early warning, and inter-departmental collaboration are crucial to controlling the spread of mosquito-borne diseases and protecting public health.

Keywords: chikungunya, mosquito-borne disease, Four Pests-free Village, Asia, vector-borne disease, vaccine, One Health

1. Introduction

Chikungunya fever is a mosquito-borne viral disease that can cause fever and severe joint pain. It is caused by a ribonucleic acid (RNA) virus belonging to the genus Alphavirus in the family Togaviridae (*1*). The Chikungunya virus (CHIKV) is transmitted by day-biting Aedes aegypti and Ae. albopictus females; after 2–12 days, patients develop an abrupt fever, severe joint pain, muscle aches, headaches, nausea, fatigue, and a rash — symptoms last days to years, but are rarely fatal (*2*). Since its re-emergence in the Indian Ocean region in 2005, CHIKV has nearly spread to all major regions inhabited by its primary vectors, the Ae. aegypti and Ae. albopictus mosquitoes (*3*). An estimated 119 countries have experienced the transmission of CHIKV, affecting 2.8 billion people (Figure 1). In epidemic settings, the average duration between two outbreaks is 6.2 years, with 8.4% of the susceptible population infected during each outbreak. There are approximately 35 million infections globally each year, primarily occurring in Southeast Asia, Africa, and the Americas (*4*).

The dense areas of Ae. aegypti and Ae. albopictus are mainly located in southern China (*5*). China is a non-endemic area for CHIKV, with most cases imported and confirmed in Guangdong and Zhejiang provinces (*6*).The provinces of Guangzhou in 2010, Zhejiang in 2017, and Yunnan in 2019 reported local outbreaks of chikungunya fever (*7*). Zhejiang Province, located in the southeastern coastal region of China, is economically active, has the highest social mobility and population density, and is thus vulnerable to infectious diseases, and particularly those related to travel-related imported diseases (*8*). A point worth noting is that in 2025, there will be another chikungunya epidemic in Guangdong Province (*9*). The epidemic was triggered by imported cases, and the climate conditions of a high temperature and high humidity after a typhoon promoted mosquito reproduction and virus transmission. Based on the epidemiological data and characteristics of

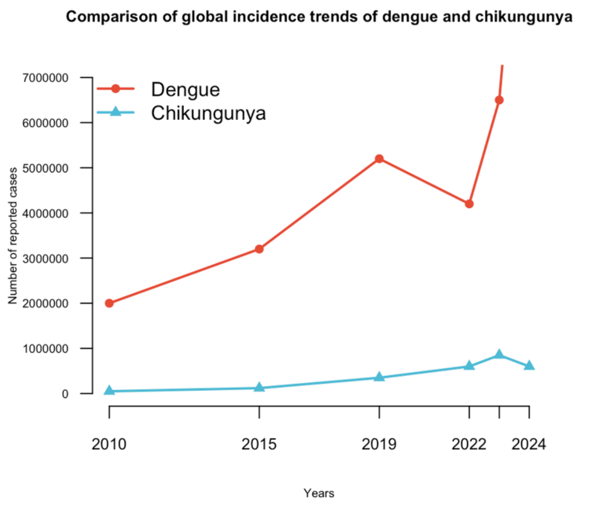

Figure 1. Comparison of global trends in the incidence of dengue and chikungunya.

chikungunya's vector ecology, this review presents the public health response measures of various countries and systematically proposes precise prevention and control strategies.

2. Viral and vector foundations

CHIKV originated in Africa over 500 years ago and was subsequently introduced to Asia. Preliminary genetic analysis of the common African lineage of CHIKV showed that the virus was divided into three genotypes, West Africa (WA), Eastern/Central/South Africa (ECSA), and Asia. ECSA can be further classified into Indian Ocean lineage (IOL) subfamilies (*2*). These genotypes are now distributed around the world, with ECSA and Asian genotypes being the main genotypes found (*10*). Ae. aegypti and Ae. albopictus are potent vectors of several arboviruses, including dengue fever (DEN), yellow fever (YF), chikungunya fever (CHIK), and Zika virus, which have significant implications for human health (*11*). Ae. aegypti mosquitoes prefer urban artificial containers, with a radius of ≈ 200 m; Ae. albopictus can breed in urban, suburban, rural, and forest environments, and it is highly adaptable to a variety of small waterlogged containers (*12*). Ae. albopictus is more ecologically adaptable and has expanded globally in 30–40 years, spreading about 13.3 times faster than Ae. aegypti (*13*). Both mosquitoes are the main vectors of dengue, Zika, and chikungunya viruses, but Ae. aegypti is more efficient at transmitting the virus, and Ae. albopictus is generally a secondary or maintenance vector (*14*).The efficiency with which Ae. aegypti mosquitoes transmit DENV and ZIKV is significantly higher than that for Ae. albopictus. The latter is highly transmissible only under specific genotypes or environmental conditions, as is the case in the Americas (*14*).

3. Epidemiological profile of chikungunya globally

Since the outbreak of CHIK around the world, there have been tens of millions of confirmed cases: Between 2015 and 2023, 909 suspected deaths due to CHIKV were reported in Brazil, where the northeastern region (such as Ceará) was a hot spot (*15*). India, Brazil, Sudan, and Thailand were countries with a sustained high incidence from 2011 to 2022, while Latin America and the Caribbean have historically had a high incidence (*16*). Over the past decade, chikungunya has broken through its traditional tropical-subtropical range and spread to Mediterranean Europe and the southern United States (*17*). Deaths mostly occur due to multi-organ infections (the brain, lungs, liver, and kidneys), central nervous system injury, and hemodynamic disorders. Survivors had fever and joint pain, while 21.9% of those who died had neurological symptoms (*e.g.*, confusion or syncope) (*15*). RT-PCR is the gold standard for diagnosis in the acute phase (within 7 days of symptom onset) and can detect viral RNA. IgM/IgG ELISA is used for convalescent diagnosis, and double serum (7–14 days apart) is required to confirm a 4-fold increase in the antibody titer. Virus isolation is time-consuming and complex due to the need for a BSL-3 laboratory and is only used for research. Rapid diagnostic tests (RDTs) have developed 43 antibody RDTs and 2 antigen RDTs worldwide, but the sensitivity varies greatly (20–100%); 23 are approved by ANVISA in Brazil but are not registered with the FDA/EMA (*18*). As of July 31, 2025, more than 5,158 cases of CHIK (Figures 2 and 3) have been confirmed in Guangdong Province, China, and a level III response has been launched in Foshan (*19,20*). The chikungunya outbreak in the region in 2025 had a faster rate of community transmission compared to dengue outbreaks in previous years in Guangdong, indicating a higher baseline vector density or earlier silent transmission. In addition, It is expected that the epidemic in Guangdong will continue for 1-2 months (Figure 4).

4. Ecological and climate factors

Air temperature determines the spread of dengue/chikungunya by affecting mosquito lifespan, bite rate, and virus replication (*21*). There is a significant spatial regression relationship between air temperature and mosquito vector density, and temperature changes can significantly affect the distribution and density of mosquito vectors, which in turn affect the transmission risk of dengue/chikungunya (*22*). WorldClim data provides high-resolution climate data on a global scale, which are valuable for studying the impact of climate factors such as temperature and precipitation on mosquito-borne diseases (*22*). The simulation results of the CMIP6 model suggest that future climate change will lead to higher temperatures and changes

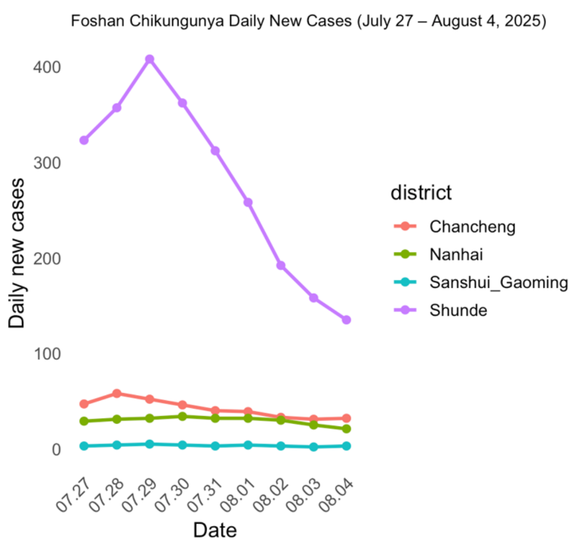

Figure 2. New chikungunya cases daily in Foshan (Jul 27– Aug 3, 2025).

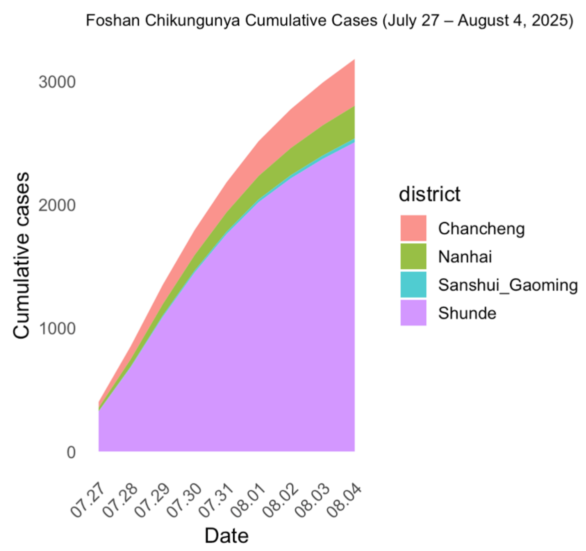

Figure 3. Cumulative chikungunya cases in Foshan (Jul 27– Aug 3, 2025).

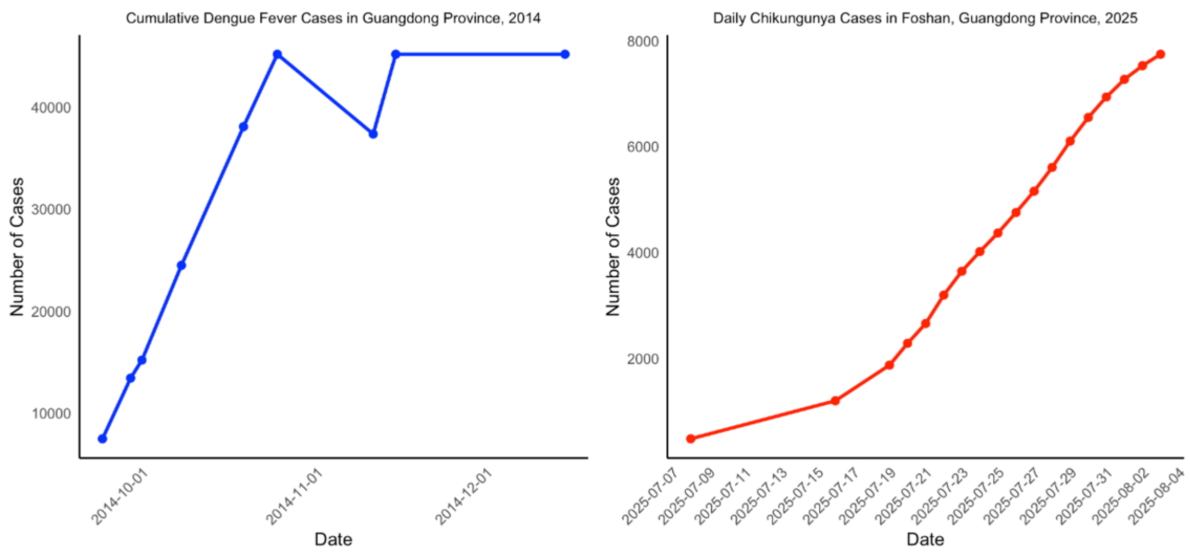

Figure 4. Comparison of the trends in the dengue fever epidemic in Guangdong in 2014 and the trends in the chikungunya epidemic in the City of Foshan, Guangdong Province in 2025.

in precipitation patterns, which may further expand the spread of mosquito-borne diseases such as dengue/chikungunya (*23*). Using the climate prediction model under the SSP5-8.5 scenario of CMIP6, researchers predict that by 2045, South China will be suitable for year-round CHIKV transmission, with an average annual increase of 1.3 times. The daily temperature difference (DTR) is more influential than the average air temperature in determining the transmission potential of dengue/chikungunya (*24,25*). The urban heat island effect can allow the virus to establish transmission in otherwise unsuitable areas, such as Europe (*24*). Indoor water containers become a breeding ground for Ae. aegypti mosquito larvae (*26*). International travel and air transport are the main drivers of cross-border transmission of mosquito-borne diseases such as chikungunya (*24*). Human communication patterns affect not only the spread of pathogens, but also daytime exposure to vectors (*27*).

5. Public health response

The Wolbachia strategy offers a promising solution to this public health challenge as a biological adaptation approach that can reduce mosquito populations and transmission capacity (*28*).There are currently no approved chikungunya or Zika vaccines, and strategic consideration is needed to develop chikungunya vaccines

Table 1. Progress of research on vaccines for major mosquito-borne diseases

Disease	Vaccine Name	Country/Institution	Current status	Key milestone
Dengue (DFV)	Qdenga (TAK-003)	Takeda, Japan	Marketed (EU, Indonesia, Brazil, *etc.*)	EU approval for ≥ 4 y, 2023
	Dengvaxia (CYD-TDV)	Sanofi-Pasteur, France	Marketed	/
	Butantan-DV	Butantan Institute & NIAID	Regulatory review Phase I/II ongoing	Phase III completed in 2023; approval anticipated in 2025
	mRNA vaccines	China, USA, Europe		First-in-human trials started in 2024
Chikungunya (CHIKV)	Vimkunya (inactivated)	Valneva, France/EU	Marketed	EU approval granted early in 2025
Zika (ZIKV)	DNA vaccine (GLS-5700)	Inovio, USA	Phase II (on hold)	First-in-human trial in Q3 2016
	mRNA vaccine (NIAID)	NIH, USA	Phase I ongoing	Trial initiated in 2019
Rift Valley Fever (RVFV)	mRNA vaccine (Afrigen)	Afrigen, South Africa & CEPI	Transition from pre-clinical to Phase I	Phase I started in 2025

(Table 1) and ensure equitable access in countries with limited resources (*29*). In November 2023, the US Food and Drug Administration (FDA) approved the VLA1553 live attenuated vaccine (brand name: IXCHIQ) for use in adults ≥ the age of 18 at risk of exposure to chikungunya (*30*). Based on 100% seroconversion and antibody levels over 12 months in a Phase 1 trial, VLA1553 proceed directly to the Phase 3 development phase (*31*). PXVX0317 (formerly VRC-CHKVLP059-00-VP) has completed Phase 1, 2, and 3 trials with a seroprotection rate of 98% in adults (*30,32*). In terms of epidemic surveillance, the association between international travel restrictions and declines in mosquito borne-disease can be assessed through epidemiological and viral genomic data. At the same time, targeted testing and monitoring of arrivals from high-risk areas can help guide public health strategies (*33*). Enhancing public health education is one of the priorities for future mosquito-borne disease prevention, addressing concerns, building trust, and ensuring that interventions are tailored to local needs through community engagement and dialogue (*34*). At present, there are some issues with this initiative, mainly because mobilizing and coordinating across departments and fields is difficult, and lack of leadership in one word. Surveillance of and research on vector-borne diseases, such as integrated vector management (IVM), should be enhanced (*34*). Since 2016, Zhejiang has promoted Four Pests-free Villages based on the "2017-2030 Global Vector Control Response" and integrated vector management, along with the One Health (OH) concept (*35-37*), which has significantly reduced the local mosquito density and thus reduced the incidence of mosquito-borne diseases (*38-40*). At the same time, China has issued a series of action guidelines for mosquito-borne diseases, aiming to provide action guidelines for high-incidence areas (*41*).

6. Conclusion

At present, the world is facing the "quadruple pressure" of climate change, the surge of people across borders, an increase in pesticide resistance, and a lag in vaccine research and development, and mosquito-borne diseases have become the latest problem with International Health Regulations. A model has predicted that the exposed population will jump from 4 billion to 5 billion by 2050. In light of this trend, China has taken the initiative to connect with the "2017-2030 Global Vector Control Response" at the international level, exported the dual-mode digital tool of the "Four Pests-free Village," and established a cross-border joint monitoring network. It continues to follow up on the WHO pre-certified live chikungunya vaccine and Wolbachia-infected mosquito release technology, and incorporate them into the national emergency technology reserve to provide a replicable and generalizable "Chinese plan" for the world.

In line with the OH concept and IVM, China has extensively integrated Zhejiang's "Four Pests-free Village" initiative with Guangdong's "sub-national sentinel framework response" experience. Zhejiang has achieved a 78% reduction in mosquito larvae density and a 90% reduction in adult mosquito density in Yuhang, Ningbo, and other places with environmental transformation. AI mosquito traps, UAV ultra-low-capacity spraying, Guangdong launched grid governance in Shunde, Foshan, subdivided 26 villages into 1,873 responsibility grids, and completed the first round of full-coverage household investigation within 4 days; the Brett index dropped from 12 to 3 within 5 days. Guangdong pioneered a joint team to ensure "disease control-housing construction-urban management-public security," inspecting 12,000 water containers per day. The experience of these two places jointly supports the "one-click start" of the national mosquito vector rapid response system. Meteorology, customs, disease control, and agriculture four-dimensional real-time data are integrating to create a national big data platform for mosquito vectors. The cross-departmental "Minimum Common Task Package for Mosquito Vector Prevention and Control" has been issued to include responsibilities as part of the appraisal if government performance. Through the dual-track mobilization of the "Digital Sentinel" applet and the grassroots grid, 24-hour direct community reporting of risks has been achieved. The network's central feature will be its ability to institute an emergency response to a cross-border imported epidemic within 7 days, providing a Chinese paradigm for ecological, technological and governance innovation to facilitate global mosquito vector prevention and control.

Acknowledgements

The authors wish to express their sincere gratitude to everyone who provided various forms of assistance during the course of preparing this review.

Funding: None.

Conflict of Interest: The authors have no conflicts of interest to disclose.

References

1. WHO. Chikungunya. *https://www.who.int/health-topics/chikungunya/#tab=tab_1* (accessed August 5, 2025)
2. de Lima Cavalcanti TYV, Pereira MR, de Paula SO, Franca RFO. A review on chikungunya virus epidemiology, pathogenesis and current vaccine development. Viruses. 2022; 14:969.
3. Roques P, Fritzer A, Dereuddre-Bosquet N, Wressnigg N, Hochreiter R, Bossevot L, Pascal Q, Guehenneux F, Bitzer A, Corbic Ramljak I, Le Grand R, Lundberg U, Meinke A. Effectiveness of CHIKV vaccine VLA1553 demonstrated by passive transfer of human sera. JCI Insight. 2022; 7:e160173.
4. Ribeiro Dos Santos G, Jawed F, Mukandavire C, *et al*. Global burden of chikungunya virus infections and the potential benefit of vaccination campaigns. Nat Med. 2025; 31:2342-9.
5. Wang G, Zhang H, Gao J, Ma Z, Du Y, Liu Q, Liu Y, Xing D, Guo X, Zhao T, Jiang Y, Li C, Zhao T. Insecticide resistance status of Aedes aegypti in border areas of Yunnan Province. Pest Manag Sci. 2024; 80:2905-2919.
6. Qiu S, Guo J, Li P, *et al*. Source-tracking of the Chinese Chikungunya viruses suggests that Indian subcontinent and Southeast Asia act as major hubs for the recent global spread of Chikungunya virus. Virol J. 2021; 18:203.
7. Ren J, Chen Z, Ling F, Liu Y, Chen E, Shi X, Guo S, Zhang R, Wang Z, Sun J. The epidemiology of Aedes-borne arboviral diseases in Zhejiang, Southeast China: A 20 years population-based surveillance study. Front Public Health. 2023; 11:1270781.
8. Wu Y, Ling F, Hou J, Guo S, Wang J, Gong Z. Will integrated surveillance systems for vectors and vector-borne diseases be the future of controlling vector-borne diseases? A practical example from China. Epidemiol Infect. 2016; 144:1895-903.
9. YiH Li SJ, Meng Z, Yan Li, JianF He, ZeF Yang, XiQ Huang, QiH Guan, ZhuF Li, Qun Lin HL, WingS Li, YuenS Lam, Lei Zhou, Min Kang. An outbreak of chikungunya fever in China — Foshan City, Guangdong Province, China, July 2025. China CDC Wkly. 2025; dio:10.46234/ccdcw2025.172.
10. Wahid B, Ali A, Rafique S, Idrees M. Global expansion of chikungunya virus: Mapping the 64-year history. Int J Infect Dis. 2017; 58:69-76.
11. Lepore L, Vanlerberghe V, Verdonck K, Metelo E, Diallo M, Van Bortel W. Vector control for Aedes aegypti and Aedes albopictus mosquitoes implemented in the field in sub-Saharan Africa: A scoping review. PLoS Negl Trop Dis. 2025; 19:e0013203.
12. Gómez M, Martinez D, Muñoz M, Ramírez JD. Aedes aegypti and Ae. albopictus microbiome/virome: New strategies for controlling arboviral transmission? Parasit Vectors. 2022; 15:287.
13. Nie P, Feng J. Niche and range shifts of Aedes aegypti and Ae. albopictus suggest that the latecomer shows a greater invasiveness. Insects. 2023; 14:810.
14. Parry R, James ME, Asgari S. Uncovering the worldwide diversity and evolution of the virome of the mosquitoes *Aedes aegypti* and *Aedes albopictus*. Microorganisms. 2021; 9:1653.
15. de Souza WM, Fumagalli MJ, de Lima STS, *et al*. Pathophysiology of chikungunya virus infection associated with fatal outcomes. Cell Host Microbe. 2024; 32:606-622.e8.
16. Grabenstein JD, Tomar AS. Global geotemporal distribution of chikungunya disease, 2011-2022. Travel Med Infect Dis. 2023; 54:102603.
17. Lim A, Shearer FM, Sewalk K, *et al.* The overlapping global distribution of dengue, chikungunya, Zika and yellow fever. Nat Commun. 2025; 16:3418.
18. Moreira J, Brasil P, Dittrich S, Siqueira AM. Mapping the global landscape of chikungunya rapid diagnostic tests: A scoping review. PLoS Negl Trop Dis. 2022; 16:e0010067.
19. Gong ZY, WZ. A wake-up call triggered by chikungunya: The urgency of applying a One Health approach to the control of Aedes-borne diseases. Chin J Infectious Diseases. 2025; doi:10.3760/cma.j.cn311365 -20250729-00251 (in Chinese)
20. Feng Y CF, Yang Y, Lu HZ. From dengue to chikungunya: Guangdong as a sentinel for arboviral threats in East Asia. BioSci Trends. 2025: 19:368-373.
21. Caldwell JM, LaBeaud AD, Lambin EF, *et al*. Climate predicts geographic and temporal variation in mosquito-borne disease dynamics on two continents. Nat Commun. 2021; 12:1233.
22. Panagos P, Ballabio C, Meusburger K, Spinoni J, Alewell C, Borrelli P. Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets. J Hydrol (Amst). 2017; 548:251-262.
23. Shakeel M, Abbas H, Ali Z, Tariq A, Almazroui M, Kader S. A novel framework for future drought characterization under ranked-based subset selection and weighted aggregative multi-modal ensemble of global climate models. J Environ Manage. 2025; 392:126692.
24. Tozan Y, Sjödin H, Muñoz Á G, Rocklöv J. Transmission

dynamics of dengue and chikungunya in a changing climate: Do we understand the eco-evolutionary response? Expert Rev Anti Infect Ther. 2020; 18:1187-1193.
25. Jian XY, Jiang YT, Wang M, Jia N, Cai T, Xing D, Li CX, Zhao TY, Guo XX, Wu JH. Effects of constant temperature and daily fluctuating temperature on the transovarial transmission and life cycle of Aedes albopictus infected with Zika virus. Front Microbiol. 2022; 13:1075362.
26. Turner EA, Clark SD, Peña-García VH, Christofferson RC. Investigating the effects of microclimate on arboviral kinetics in Aedes aegypti. Pathogens. 2024; 13:1105.
27. Knoblauch S, Heidecke J, de ARAA, *et al*. Modeling Intraday Aedes-human exposure dynamics enhances dengue risk prediction. Sci Rep. 2025; 15:7994.
28. Branda F, Cella E, Scarpa F, Slavov SN, Bevivino A, Moretti R, Degafu AL, Pecchia L, Rizzo A, Defilippo F, Moreno A, Ceccarelli G, Alcantara LCJ, Ferreira A, Ciccozzi M, Giovanetti M. Wolbachia-based approaches to controlling mosquito-borne viral threats: Innovations, AI integration, and future directions in the context of climate change. Viruses. 2024; 16:1868
29. Lee D, Kim K. A practical approach to multifaceted perspectives for sustainable international collaboration on mosquito-borne diseases in Southeast Asia. Acta Trop. 2024; 260:107481.
30. Weber WC, Streblow DN, Coffey LL. Chikungunya virus vaccines: A review of IXCHIQ and PXVX0317 from pre-clinical evaluation to licensure. BioDrugs. 2024; 38:727-742.
31. Chen LH, Fritzer A, Hochreiter R, Dubischar K, Meyer S. From bench to clinic: The development of VLA1553/IXCHIQ, a live-attenuated chikungunya vaccine. J Travel Med. 2024; 31:taae123.
32. Rosso A, Flacco ME, Cioni G, Tiseo M, Imperiali G, Bianconi A, Fiore M, Calò GL, Orazi V, Troia A, Manzoli L. Immunogenicity and safety of chikungunya vaccines: A systematic review and meta-analysis. Vaccines (Basel). 2024; 12:969.
33. Li N, Feng Y, Vrancken B, Chen Y, Dong L, Yang Q, Kraemer MUG, Pybus OG, Zhang H, Brady OJ, Tian H. Assessing the impact of COVID-19 border restrictions on dengue transmission in Yunnan Province, China: An observational epidemiological and phylogenetic analysis. Lancet Reg Health West Pac. 2021; 14:100259.
34. Kulkarni MA, Duguay C, Ost K. Charting the evidence for climate change impacts on the global spread of malaria and dengue and adaptive responses: A scoping review of reviews. Global Health. 2022; 18:1.
35. Winkler AS, Brux CM, Carabin H, *et al*. The Lancet One Health Commission: Harnessing our interconnectedness for equitable, sustainable, and healthy socioecological systems. Lancet. 2025; 406:501-570
36. Zhang W, Wang J, Liu Q, Gong Z. A review of pathogens transmitted by the container-inhabiting mosquitoes, Aedes Albopictus, A global public health threat. China CDC Wkly. 2023; 5:984-990.
37. Dantas-Torres F, Chomel BB, Otranto D. Ticks and tick-borne diseases: A One Health perspective. Trends Parasitol. 2012; 28:437-446.
38. Ni J, Wang J, Zhang W, Chen E, Gao Y, Sun J, Huang W, Xia J, Zeng W, Guo J, Gong Z. Sustainable control and integrated management through a One Health approach to mitigate vector-borne disease. One Health. 2025; 20:101018.
39. Ni J, Wang J, Fang C, Zhang W, Gong Z. A review of the latest control strategies for mosquito-borne diseases. China CDC Wkly. 2024; 6:852-856.
40. Gong ZY W, Li YF, Sun JM, Ni J, Gao Y, Xia J, Guo JX. Study on strategies of "four-pests free village"countryside sustainable vector management under the "One Health" in Zhejiang Province, China. Disease Surveillance. 2025; 40:1-6. (in Chinese)
41. Xinhua. China unveils 2025-2030 plan to promote healthy environments 2025 *https://govt.chinadaily.com.cn/s/202508/05/WS6891b3b0498edec913cdff15/china-unveils-2025-2030-plan-to-promote-healthy-environments.html*. (accessed August 5, 2025)

Received July 23, 2025; Revised August 5, 2025; Accepted August 7, 2025.

[§]These authors contributed equally to this work.
**Address correspondence to:*
Zhenyu Gong, Department of Communicable Disease Control and Prevention, Zhejiang Provincial Center for Disease Control and Prevention, Hangzhou 310051, China.
E-mail: zhygong@cdc.zj.cn

Released online in J-STAGE as advance publication August 8, 2025.