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Asian Pacific Journal of Tropical Medicine

apjtm.org

doi: 10.4103/apjtm.apjtm_432_25

Integrating behavioral ecology into dengue vector risk forecasting

To the Editor: We read with interest the article by Wang *et al.*, titled "Modeling the spread risk of dengue vector *Aedes albopictus* caused by environmental factors in Shanghai, China"[1]. The use of ensemble ecological niche models to map *Aedes albopictus* distribution in urban Shanghai is both timely and methodologically sound. The identified drivers—vegetation index, temperature, and proximity to water—are well-known contributors to vector proliferation. However, one dimension remains notably underrepresented: human behavioral factors.

Urban dengue transmission is not solely driven by environmental suitability but is also shaped by socio-behavioral patterns such as water storage practices, waste disposal habits, and outdoor activity during peak mosquito biting hours[2]. These factors influence both the availability of breeding habitats and the frequency of mosquito–human contact.

For instance, previous studies in Asian cities have shown that domestic containers, roof gutters, and ornamental plants are major breeding sources—even in zones with low Normalized Difference Vegetation Index[3]. Moreover, certain high-density neighborhoods may paradoxically exhibit lower risk due to sustained vector control engagement or public health awareness[4].

To enhance the real-world application of risk prediction, we propose that future models incorporate behavioral indicators—such as household water usage surveys or proxy measures from urban zoning data. Such hybrid eco-behavioral models could more accurately identify hotspots where vector control interventions would be most effective.

Wang *et al.*[1] have set a strong ecological baseline. As the urban environment becomes increasingly complex, integrating human factors will be vital to realizing the full potential of precision vector control. This approach is in line with the World Health Organization's Global Vector Control Response 2017–2030, which emphasizes integrated entomological and community-based strategies for precision vector control[5].

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Conflict of interest statement

The authors declare no conflicts of interest related to the research, authorship, or publication of this article.

Funding

This work received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

NKR contributed to conceptualization, literature review, writing—original draft, and writing—review and editing. SKR provided supervision, formal analysis, validation, and writing—review and editing.

AI declaration

The authors used computational tools for grammar and language editing during manuscript preparation.

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How to cite this article: Rattanapitoon NK, Rattanapitoon SK. Integrating behavioral ecology into dengue vector risk forecasting. Asian Pac J Trop Med 2025; 18(8): 380-382.

Article history: Received 28 July 2025 Revision 25 August 2025
Accepted 26 August 2025 Available online 29 August 2025

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Authors' Reply: We sincerely thank the authors for their insightful commentary on our study titled "Modeling the spread risk of dengue vector *Aedes albopictus* influenced by environmental factors in Shanghai, China"[1]. Their emphasis on the role of human behavioral factors in shaping dengue transmission dynamics represents an important and timely contribution to the ongoing discourse. We greatly value this opportunity to respond in detail to their observations and to further clarify the scope and future directions of our work.

Li *et al.*[2] reported that *Aedes albopictus* prospered most in urban areas, where larval-positive habitats were most abundant, pupal density nearly doubles, and adult populations were about three times greater than in suburban or rural settings. Urban larvae develop faster, pupate more successfully, and produce adults that live longer, collectively enhancing mosquito fitness. A review also showed that higher population density and human activities in urban areas resulted in a higher number of artificial containers such as discarded tires, disposable food cans and flower pots, which are favorable breeding habitats for *Aedes albopictus*[3]. Wen *et al*. incorporated the distance to social gathering places when estimating the spatial risk of dengue fever, underscoring the critical role of social and behavioral variables in shaping transmission dynamics[4]. These findings highlight that urbanization not only increases breeding opportunities but also strengthens life-stage performance, thereby amplifying vectorial capacity and the likelihood of dengue transmission.

As noted in our discussion, our current model was limited by data availability and thus focused primarily on ecological variables, due to the lack of fine-scale socio-behavioral data—such as household water practices or public space usage—at the 100 m × 100 m resolution. Nevertheless, we recognize that incorporating these variables would substantially improve both the realism of the model and the precision of targeted interventions. In our modeling process, we have already incorporated the Human Footprint Index (HFI) and the Human Influence Index (HII) as explanatory variables[1]. While these indices do not directly capture household-level practices such as water storage, waste disposal, or daily mobility, they serve as useful proxies for the intensity of human activity in urban settings. In doing so, they reflect the aggregate degree of anthropogenic disturbance on the environment and can thus indirectly characterize the ecological conditions that favor the proliferation of *Aedes* breeding habitats.

This approach is consistent with methodologies applied in the modeling of other vector-borne diseases. For instance, in schistosomiasis risk prediction[5,6], researchers have employed night-time light indices as proxies for urbanization and socioeconomic activity, enabling the delineation of high-risk areas for both parasites and intermediate snail hosts. Such applications illustrate how remotely sensed behavioral proxies can effectively bridge ecological suitability with human-driven factors of disease transmission[7,8]. Building on these insights, we see strong potential to enhance dengue vector risk models by integrating ecological and behavioral dimensions within a unified analytical framework.

In line with the World Health Organization's global vector control response 2017–2030, we concur that precision public health requires a multidisciplinary approach[9]. Moving forward, we aim to maintain the robustness of ecological predictors while systematically incorporating behavior-based indicators derived from household surveys (*e.g.*, water storage practices, community participation in vector control) as well as proxy measures at the urban zoning level (*e.g.*, population density, green space availability, and public facility utilization). We believe that such an eco–behavioral hybrid modeling framework will not only capture the inherent complexity of dengue transmission but also provide actionable evidence to inform geographically targeted interventions and policy decisions at the community scale.

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How to cite this article: Wang JM, Gong YF, Zhou YB. Integrating behavioral ecology into dengue vector risk forecasting-Authors' reply. Asian Pac J Trop Med 2025; 18(5): 240.

doi: 10.4103/apjtm.apjtm_482_25

Conflict of interest statement

The authors declare no conflicts of interest related to the research, authorship, or publication of this article.

Funding

This work is supported by Three-Year Initiative Plan for Strengthening Public Health System Construction in Shanghai (2023-2025) Key Discipline Project (No. GWVI-11.1-12).

Authors' contributions

JMW and YFG contributed to conceptualization, literature review, writing—original draft, and writing—review and editing. YBZ provided supervision, formal analysis, validation, and writing—review and editing.

AI declaration

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Edited by Zhang Q, Lei Y, Pan Y