Applying Artificial Intelligence to Predict Mosquito Microbiome–Mediated Resistance: A Proposed Framework for Next-Generation Vector Control

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Abstract

Mosquito-borne diseases continue to impose a significant global health burden, causing millions of infections and deaths annually, and control efforts are increasingly compromised by the rapid emergence of insecticide resistance. While genetic mutuations contributing to resistance have been extensively studied, emerging evidence suggests that the mosquito microbiome plays a substantial yet underexplored role in modulating insecticide tolerance through mechanisms such as detoxification, metabolic regulation, and immune modulation. The high diversity and complexity of microbial communities, coupled with their interactions with environmental and physiological factors, make traditional analytical approaches insufficient to capture patterns predictive of resistance. This study proposes the development of an artifical intelligence (AI) based framework to predict microbiome-mediated insecticide resistance in mosquito populations. High-throughput sequencing will be employed to comprehensively profile bacterial communities from both field-collected and laboratory-reared mosquitoes exhibiting varying resistance phenotypes. Machine learning algorithms, including random forests, support vector machines, and neural network, will be used to indentify microbial signatures associated with resistance. Feature selection and model interpretability techniques will highlight key microbial taxa and functional pathways potentially contributing to tolerance, while environmental and physiological covariates such as breeding habitat, mosquito age, and microclimatic variables will be integrated to improve predictive accuracy. The anticipated outcomes include the indetification of specific microbial taxa and community patterns predictive of resistance, and the development of an AI-driven diagnostic tool capable of rapid classification of mosquito populations based on microbiome profiles. By bridging high-resolution microbiome profiling with AI analytics, this approach aims to provide objective, scalable, and data-driven tools for early detection of emerging insecticide resistance. The expected impact includes informing precision vector management strategies, guiding sustainable interventions, and contributing to the global effort to mitigate the burden of mosquito-borne diseases through innovative, integrative approaches that combine microbiome science, computational analytics, and applied vector control.

Keywords

Mosquito-borne Diseases, Insecticide Resistance, Mosquito Microbiome, Artificial Intelligence, Machine Learning, Microbial Community Profiling, Vector Control, Predictive Diagnostics