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LarvaTracker: A Robot Solution for Locating and Treating Mosquito Breeding Sites

Rodante J. Santos[1*], Kris Danielle T. Santiago[1], Kurt Russel D. Sison[1], Harlan M. Sunga, Kristine M. Vergara, Asil Kastle S. Dela Cruz and Ruby Rosa N. Puno
[1]*Pampanga State University*
[*]*rrnpuno@pampangastateu.edu.ph*

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ABSTRACT

This study developed LarvaTracker, an autonomous robotic system designed to identify and treat mosquito breeding sites, specifically targeting the larvae of Aedes aegypti and Aedes albopictus. The platform integrates environmental sensors for monitoring pH, turbidity, dissolved oxygen, and temperature with a YOLOv8 object detection model to recognize high-risk containers such as bamboo stumps, tires, and plant pots. Built on a hardware architecture of Raspberry Pi 5 and ESP32 with a solar-powered supply, the system utilizes an autonomous navigation module and a precision sprayer to execute targeted larvicide application with minimal human intervention. Field testing conducted at Bamboo Park in Lubao, Pampanga, demonstrated high detection accuracy, successful dispensing, and reliable real-time data reporting via a web-based dashboard. These results confirm LarvaTracker's effectiveness in reducing potential habitats and supporting public health efforts against vector-borne diseases. Future enhancements should focus on expanding the object detection dataset and integrating predictive weather data for dynamic patrol scheduling, establishing LarvaTracker as a sustainable and promising automated intervention for outdoor mosquito management.

Keywords: *Dissolved oxygen, Microcontroller, NTU, pH level, Turbidity*

INTRODUCTION

Mosquito breeding sites, predominantly found in stagnant water and artificial containers, represent a critical public health challenge in urban environments where diseases such as dengue, Zika, and chikungunya is prevalent. While effective control traditionally relies on environmental management and community participation, hidden and inaccessible breeding grounds remain a persistent obstacle to total eradication. Recent scholarship underscores the need for innovative strategies; for instance, Baigorria and Romero (2024) advocate for integrating human-controlled breeding sites into management frameworks, while Soria et al. (2024) and Tan et al. (2024) emphasize the success of community-based educational interventions and integrated efforts within local health stations. In the Philippines, the "May Piso sa Mosquito" program (GMA News, 2025) exemplifies the use of incentives to drive community action, yet localized reports from areas like Lubao, Pampanga—which recorded 298 dengue cases in 2024—reveal that manual interventions often suffer from resource constraints and the physical limitations of caretakers in accessing cryptic habitats. Furthermore, evidence from related environmental sectors in the Philippines suggests that digital leadership and technological integration can significantly enhance operational efficiency, particularly in water resource management (Balagtas & Mallari, 2025).

The complexity of mosquito control is further compounded by the high adaptability of species like Aedes aegypti and Aedes albopictus. Habitat studies indicate that tires and plastic containers serve as primary breeding reservoirs (Mbanzulu et al., 2022; Salamat et al., 2013), with environmental factors such as pH, salinity, dissolved oxygen, and temperature significantly influencing population density (Medeiros-Sousa et al., 2022). Given these biological and logistical challenges, there is an urgent need for automated solutions that can augment traditional vector control. The LarvaTracker system is proposed as an autonomous robotic platform designed to bridge these gaps. Specifically, the project aims to design a robot that can automatically detect breeding sites using a YOLOv8 object detection model, apply precise treatments to minimize human exposure, and navigate autonomously to ensure continuous monitoring even in hard-to-reach areas.

While the LarvaTracker is optimized for small, artificial containers rather than large water bodies, its implementation offers significant public health value. The system enhances the precision of larvicide application, reducing environmental chemical impact while providing real-time data for health agencies. By addressing the limitations of manual labor and human-controlled monitoring, LarvaTracker establishes a sustainable, tech-driven foundation for disease prevention and environmental management, ultimately reducing the health risks associated with vector-borne epidemics in urban communities.

METHODS

Research Design

This study utilized a combination of developmental and applied research methodologies to design and evaluate LarvaTracker. The development process followed an Agile methodology, organized into sprints and weekly milestones to handle modules such as scheduling, detection, notification, and operation control.

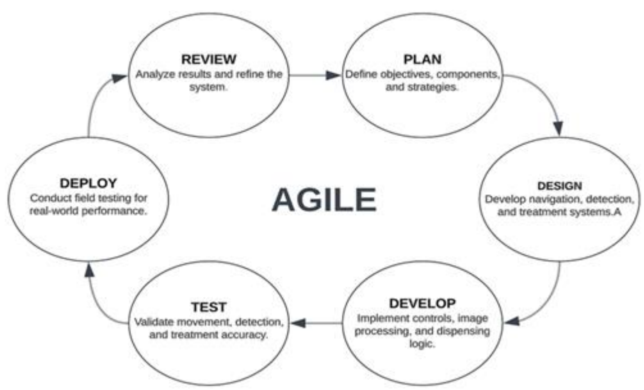

Figure 1. *Agile Method*

Research Locale

The system was deployed and tested at Bamboo Park, Barangay Sta. Catalina, Lubao, Pampanga, a location with a high prevalence of mosquito breeding sites.

Sampling Technique and Testing

The evaluation phase involved 10 purposely selected park maintenance staff and local personnel with experience in mosquito management. The device was built on a solar-powered architecture using a Raspberry Pi 5 for main processing and an ESP32 for low-level tasks. It features six DC motors and utilized GPS and a magnetometer for real-time location tracking.

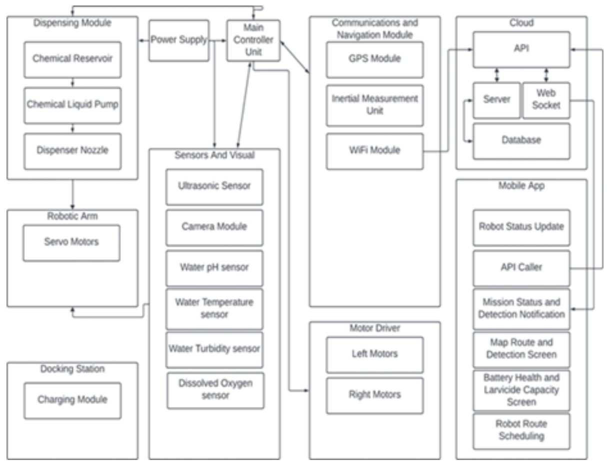

Figure 2. *Block Diagram*

The system integrates sensors for pH, turbidity, DO, and temperature, alongside a camera module trained on a YOLOv8 model to identify containers like bamboo stumps and tires. A relay-controlled pump system dispenses larvicide based on WHO-standardized doses. The software stack was developed using Python 3.10, featuring a FastAPI/Flask-SocketIO backend and a React.js frontend.

Figure 3. *Complete Integration of Robot Hardware Components*

Hardware modules underwent unit and integration testing to ensure stable communication. User Acceptance Testing (UAT) was conducted in "Auto mode," and the administrative dashboard's usability was reviewed by participants.

Table 1. *Rubrics for Sensors*

Parameter	Range for Possible Breeding Site	Rubric Criteria	Interpretation
pH	5.26-8.41	Reading within 5.26 to 8.41	Suitable for mosquito breeding
	Outside this range	Reading outside 5.26 to 8.41	Less suitable or unlikely breeding site
Dissolved Oxygen (DO%)	0.5 – 2.6	Reading within 0.5% to 2.6%	Suitable for mosquito breeding
	Outside this range	Reading outside 0.5% to 2.6%	Less suitable or unlikely breeding site
Turbidity (NTU)	0.29 – 731.00	Reading within 0.29 to 731 NTU	Suitable for mosquito breeding
	Outside this range	Reading outside 0.29 to 731 NTU	Less suitable or unlikely breeding site
Temperature (°C)	26.80 – 33.20	Reading within 26.8°C to 33.2°C	Suitable for mosquito breeding
	Outside this range	Reading outside 26.8°C to 33.2°C	Less suitable or unlikely breeding site

RESULTS AND DISCUSSION

This section presents findings regarding hardware functionality, software performance, and overall effectiveness. Testing confirmed the accuracy and reliability of the sensors in analyzing water quality parameters.

Table 2. *Results Summary Validating Project Objectives*

Objective	Test/Method	Result Obtained
Automatically detect mosquito breeding sites	Field test with YOLOv8 object detection on plant pots, tires, and water containers	90.6% detection accuracy in varied lighting conditions
Automatically treat detected breeding sites	Sprayer triggered upon verified detection	Precise spray activation only on valid sites
Autonomous navigation and monitoring	GPS-based patrol simulation with auto-return function	Robot completed full route and returned to docking station
Sustainable mosquito control in hard-to-reach areas	Repeated runs in semi-obstructed test zones	Navigation and detection worked even in low-access areas
Reduce human intervention in mosquito control	Continuous Auto Mode operation	Minimal manual input required during patrol and treatment

The robot consistently detected breeding sites with over 90% accuracy using YOLOv8, even under varied lighting. Upon detection, the sprayer system applied treatment only to confirmed sites, ensuring targeted control. GPS-based navigation allowed for autonomous patrol routes and reliable docking.

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Table 3. *Objective 1 – Detection Capability*

Survey Statement	Mean Score	Interpretation
The robot can accurately detect mosquito breeding sites.	4.4	Highly Effective
The detection system works effectively across different environments.	4.1	Highly Effective
The robot helps identify breeding areas faster than traditional methods.	4.5	Highly Effective

The robot's ability to detect sites was rated highly effective by users, demonstrating accuracy and time-efficiency.

Table 4. *Objective 2 – Treatment Capability*

Survey Statement	Mean Score	Interpretation
The robot applies treatment with consistent accuracy.	4.2	Highly Effective
The process minimizes human exposure to chemicals.	4.8	Highly Effective
The robot distinguishes between breeding and non-target areas.	4.2	Highly Effective

Users affirmed effective and safe treatment application, noting high scores in treatment accuracy and chemical exposure reduction.

Table 5. *Objective 3 – Autonomous Navigation and Return*

Survey Statement	Mean Score	Interpretation
The robot can autonomously navigate various terrains.	4.1	Highly Effective
The robot can access areas typically inaccessible to humans.	4.7	Highly Effective
The robot reliably returns to its docking station.	4.9	Highly Effective
The return function ensures readiness for use.	4.2	Highly Effective

The robot exhibited robust autonomous capabilities in complex environments, maintaining continuous operation with minimal human intervention.

CONCLUSION

This project successfully developed an autonomous robotic system capable of detecting, treating, and monitoring mosquito breeding sites, targeting Aedes aegypti and Aedes albopictus. Using environmental sensors (pH, turbidity, dissolved oxygen, temperature), the robot accurately identified mosquito-prone areas such as bamboo stumps, plant pots, cement planters, and tires. It performed effectively across key functions: detecting breeding sites, applying targeted larvicide treatments with minimal human exposure, and autonomously navigating and docking. Its ability to access confined spaces enhances its potential for urban and suburban vector control. Field tests and user feedback confirmed the system's reliability and value as a sustainable mosquito control solution. Overall, LarvaTracker offers faster, more accurate data collection compared to manual inspection, enabling quicker response times and more effective mosquito control strategies.

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