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SUPSI

# Final Report

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| Reference no.: | **BAG-D-FCFF3401/390** |
| Reporting Period: | **08 July 2025 – 24 February 2026** |
| Project title: | **Assessment of smart trap technology for monitoring arbovirus vector mosquitoes (*Aedes albopictus* and *Culex pipiens*) in the Swiss urban surveillance system: evaluation conducted in the canton of Geneva during the 2025 summer season** |
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# 1. Background and scope of the study

The urban-dwelling invasive mosquito species *Aedes albopictus*, commonly known as the tiger mosquito, is spreading increasingly across Switzerland—driven in part by climate change—and poses a growing public health concern due to its ability to transmit dangerous pathogens such as dengue, chikungunya, and Zika viruses. First detected in the Canton of Ticino in 2003, this species has since appeared north of the Alps, reaching most cantons, with established populations particularly in the cantons of Geneva and Basel-City. Its proliferation not only heightens the risk of disease transmission but also causes significant nuisance in densely populated areas.

The native mosquito species *Culex pipiens*, which can thrive in both urban and natural environments, represents an additional public health concern due to its role as a vector of West Nile virus (WNV).

For effective control, it is important to know when and where these organisms occur, spread, and behave. Monitoring is therefore essential for any potential control measures and thus for reducing the risk of disease. Currently, the most effective method for large-scale surveillance of *Ae. albopictus* is the use of ovitraps, a low-cost approach in terms of materials, though labor-intensive to manage and analyse. Adult mosquito traps offer and alternative means of detecting this species, but they are expensive and require significant operational effort, restricting their use to selected areas. Consequently, many cantons struggle to maintain robust monitoring systems.

The Spanish company Irideon SL. (Barcelona, Spain; www.irideon.es), following an experimental development phase, is preparing to distribute a “Smart Trap Technology” intended to enable automated and digitally controlled monitoring of *Aedes albopictus* (Figure 1). The novel system VECTRACK, based on a specific optical sensor mounted on a commercial adult trap and combined with a supervised machine learning algorithm, enables automated counting and determination of *Aedes* and *Culex* mosquitoes by genus and sex. The system provides real-time data directly to the user’s computer interface. A key advantage of this trap is that it requires no manual intervention beyond the initial deployment.

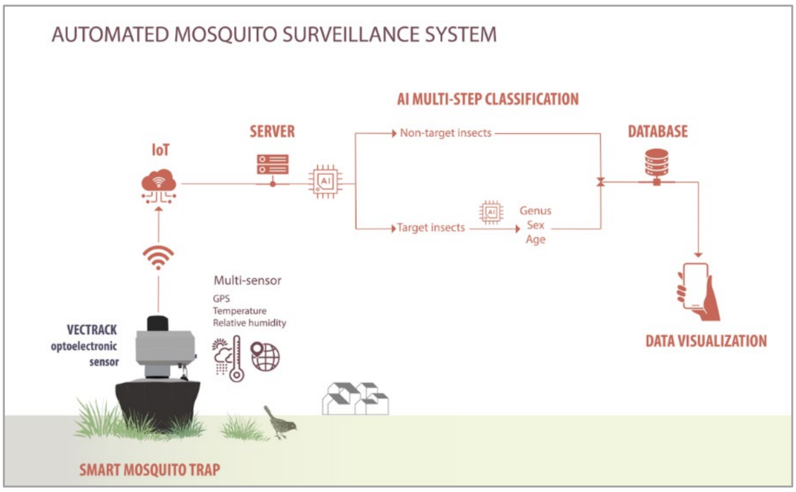


Figure 1. Diagram of the automated mosquito surveillance system developed by IRIDEON, featuring the VECTRACK sensor integrated into a mosquito commercial trap and connected to the server via IoT. Source: https://www.e4warning.eu/2024/07/12/vectrack-smart-traps-enhancing-mosquito-surveillance-with-cutting-edge-technology/.

Two previous trials showed that VECTRACK can provide good approximations of the real adult counts (Gonzalez-Perez et al., 2024; Micocci et al., 2024). Therefore, the present study aims at estimating the precision of this tool in Switzerland in real field conditions and its practical applicability for early detection and control of the tiger mosquito. The results of the study will serve as the basis for evaluating a larger use of these traps in Switzerland to monitor adult abundances.

## 2. Materials and methods

The Canton of Geneva was selected as the study area because the tiger mosquito is spreading rapidly there (Figure 2), yet no dedicated surveillance system has been established to date. Nevertheless, control measures are already in place, primarily through the routine application of larvicides in public areas.

The experimental design was developed by Zurich Data Scientists (ZDS) under the supervision of the Vector Ecology Unit (ECOVET) at the Institute of Microbiology, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), and the Cantonal Office for Agriculture and Nature (OCAN), Department of Territory, Canton Geneva. According to the manufacturer of VECTRACK, a minimum of five smart traps is required to implement surveillance in the Canton of Geneva. Consequently, five smart traps were deployed at five suburban sites across the canton (Figures 2 and 3). The municipalities were selected based on tiger mosquito densities reported by citizens through the existing public reporting channels:

1. Lancy – high density for the past 2-3 years;
2. Thonex – high density for the past 2-3 years;
3. Chêne-Bourg – high density reported since 2024;
4. Vernier – low density in 2024;
5. Versoix – no detections in 2024, with first sightings at the end of the season.

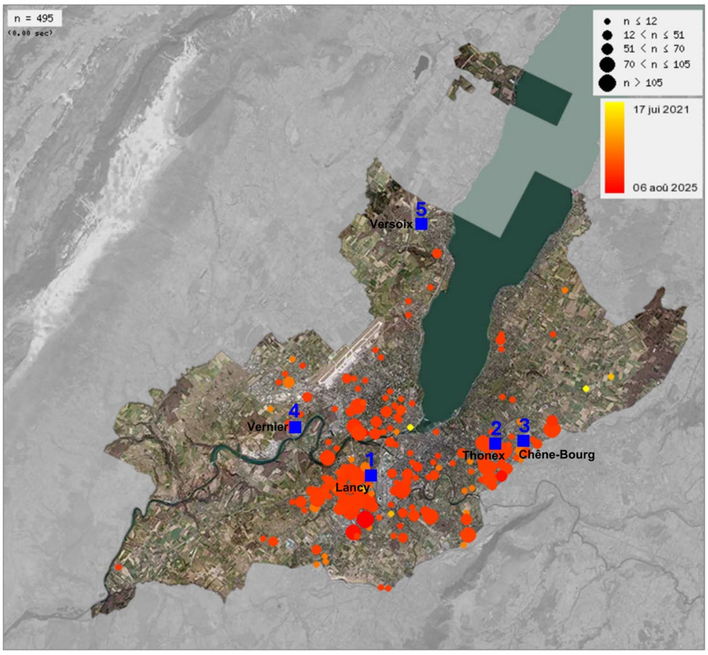


Figure 2. Locations of reported tiger mosquitoes (round dots) in the Canton of Geneva between 2021 and 2025 and the five sites (blue squares) selected for smart trap deployment in summer 2025. Image modified from https://www.faunegeneve.ch/index.php?m_id=30038.

Each smart trap consisted of a BG-Sentinel adult mosquito suction trap (Biogents AG, Regensburg, Germany) equipped with a VECTRACK sensor mounted directly at the trap entrance (Figure 3). At each site, traps were positioned to ensure shaded conditions, proximity to vegetation, protection from rain and wind, access to electricity, and minimal risk of theft. The mosquito attractant BG-Mozzibait (Biogents) was placed at the bottom of each trap.


Figure 3. The specific spots where the traps were placed. The Versoix trap also had a sensor, even though it is not pictured here.

The five smart traps operated from 2 July to 3 October 2025. Throughout this period, they functioned continuously, recording insect captures over the entire three-months monitoring period. To evaluate how closely the machine-generated counts matched the true number of insects captured, ground-truth data were collected. Specifically, the catch bags containing trapped specimens were removed and manually examined to determine actual counts. These manually obtained counts were then compared with those produced by the device. The BG-Sentinel catch bags were collected every 24 hours for five consecutive days every two weeks (Figure 4). As a result, the first collection of each five-day sampling session contained all insects accumulated since the final sampling of the previous session (or, for the first session, since the initial activation of the traps). At each collection, the catch bags were placed in a container with a cotton pad soaked in alcohol to euthanize the mosquitoes and were stored at ambient temperature until the end of the session. Afterwards, the 25 catch bags were mailed to SUPSI, where the captured mosquitoes were counted and morphologically identified to species and sex.


Figure 4. Period of activity of the smart traps (pink cells) and schedule of catch bags collection (days circled in red).

### Data analysis

The statistical analyses aimed to answer the question: “To what extent do the machine-determined counts of adult mosquitoes match the actual human-determined counts?” A graphical analysis was conducted by plotting the true counts against the machine-generated counts for each trapping session and estimating the correlation between the two. This procedure was repeated across all aggregation levels. The percentage error was estimated to provide stakeholders with an interpretable measure of precision, enabling them to assess whether the cost savings and scalability of the devices justify their lower accuracy.

## 3. Results and discussion

### Data overview

Data were aggregated at the experiment level for each smart trap. Each experiment typically corresponds to one day of observation; however, the first experiment within each sampling round may last either 5 or 17 days. During each experiment, mosquitoes enter the trap and cannot leave.

The smart trap automatically assigns each captured mosquito to a sex–genus category:

- *Culex* or *Aedes*
- male or female

After each experiment ends, the laboratory manually identifies and counts all mosquitoes collected in the catch bag. Thus, for each experiment, the dataset contains the number of mosquitoes recorded per sex–genus category by both the smart trap and the laboratory.

### Total mosquito counts

Across all experiments and traps, the smart trap recorded a total of 341 mosquitoes, while the laboratory recorded 334 mosquitoes (difference: 7). Assuming that the number of mosquitoes missed by the smart trap is negligible, the difference can be used to estimate how many mosquitoes were predated before reaching the lab. The estimated proportion of likely predated mosquitoes was 2.1%.

### Zero counts

Across all sex–genus categories and all experiments, 488 observations were evaluated. In 332 cases (68%), both the smart trap and the laboratory recorded zero mosquitoes.

### Correct classifications (non-zero cases)

Excluding zero counts, 156 sex–genus observations were evaluated. In 31 of these (19.9%), the smart trap and the laboratory reported identical counts, indicating that **this percentage is very low**.

### Classification of mosquitoes by sex–genus category

For each sex–genus category, the following were calculated:

- The number of mosquitoes counted by both the smart trap and the laboratory.
- The number counted only by the smart trap.
- The number counted only by the laboratory.

The counts were summed across sex–genus categories to obtain an overall classification summary for each experiment.

### Overall classification summary (all experiments)

The aggregated classification matrix across all experiments was:

| | Counted in laboratory | Not counted in laboratory |
|---|---|---|
| **Counted in smart trap** | 165 | 176 |
| **Not counted in smart trap** | 169 | NA |

The table shows how many mosquitoes were correctly identified within the same group (e.g. *Aedes* females) by both methods, and how many were classified differently by one method or the other. This estimate is considered optimistic, because “double errors” may occur (e.g., if the trap misassigns individuals between categories in both directions, which can partially cancel out the true error). The error (NA) reported at the bottom right (Not counted in smart trap and Not counted in laboratory) cannot be directly observed, because we only have the final mosquito count from the catch bag. If the experiments were performed in the laboratory, we might observe a mosquito passing through the trap without being identified by either method; in that case, this cell could contain a value. We lack ground truth for cases where both systems may have simultaneously misidentified or missed the same mosquito.

### Proportion of classifications (all genera)

The proportions corresponding to the table above were:

| | Counted in laboratory | Not counted in laboratory |
|---|---|---|
| **Counted in smart trap** | 32.4 | 34.5 |
| **Not counted in smart trap** | 33.1 | NA |

**In practice, the smart trap correctly assigns the exact category (i.e., the precise number of mosquitoes within a specific sex–genus group, such as "female *Aedes*") only about one third of the time.**

### Scatter Plots

Scatter plots were produced to compare smart-trap and laboratory counts for each sex–genus category. Figure 5 shows the scatter plot for the counts made by smart traps versus those made in laboratory. Each dot corresponds to the number of mosquitoes detected during a measurement in a given experiment, for each genus and sex. The bisector (red line) indicates where the points would lie if the counts from the two methods matched exactly. Points below the bisector indicate individuals misassigned or missed by the smart trap. Points above the bisector may reflect either misassignment by the smart trap or mosquitoes missed by the laboratory (e.g., due to predation or escape).

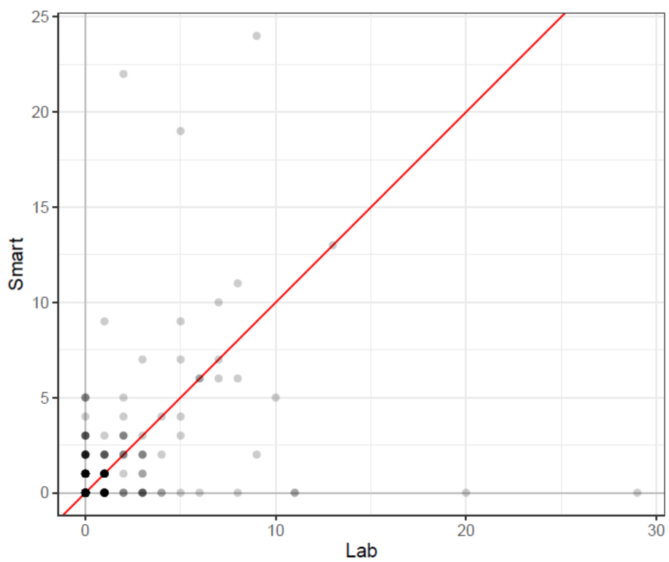


Figure 5. Scatter plot comparing smart trap and laboratory counts. The red bisector indicates where the points would lie if the counts from the two methods matched exactly.

**We notice that there are quite a lot of mosquitoes that were assigned to the wrong sex-genus category by the smart trap.**

We also wanted to understand whether a genus is easier to detect compared to the other, therefore for each given experiment we plotted the number of *Aedes* (Figure 6 left) or *Culex* (Figure 6 right) mosquitoes (no distinction between females and males yet) counted by smart trap and the number counted by the laboratory. We also calculated Pearson correlations between laboratory and smart trap counts for each aggregation level, assuming a linear one-to-one relationship. Pearson's correlation was selected because it measures linear agreement, which matches the expected one-to-one relationship between smart trap and laboratory counts. Rank-based methods (Spearman, Kendall) would be inappropriate here because they could indicate perfect correlation even if the smart trap consistently over- or underestimates counts.

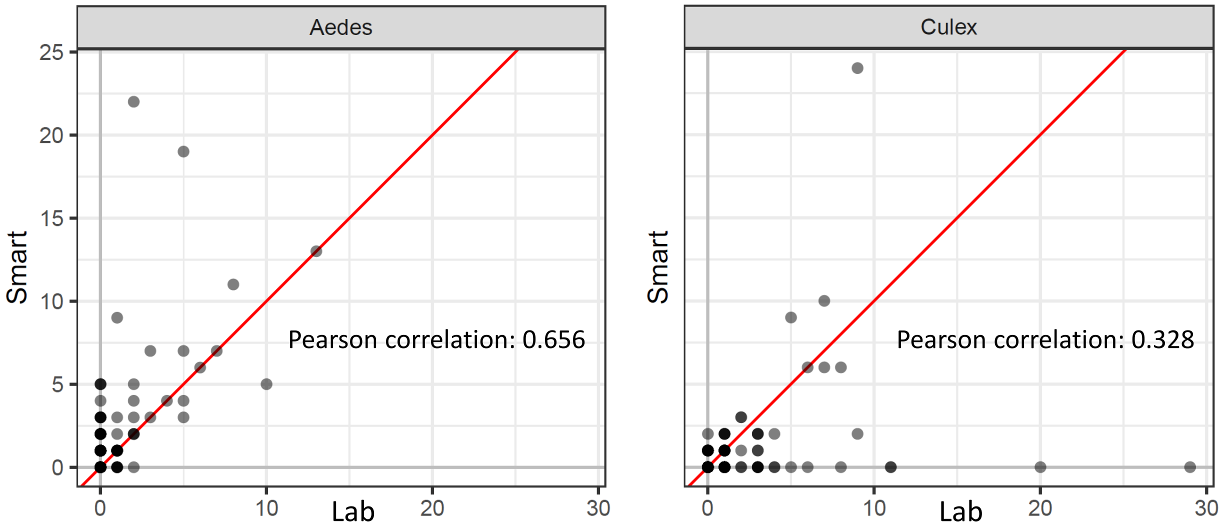


Figure 6. Scatter plots comparing smart-trap and laboratory counts for *Aedes* (left) and *Culex* (right) genera. The red bisector indicates where the points would lie if the counts from the two methods matched exactly.

We see that there are a lot of points at the coordinate (0, 0). This means that both laboratory and smart trap did not detect any mosquitoes for a given experiment. If a point lies on the bisector, it means that both methods counted the same number of mosquitoes. The darker a dot is, the more observations there are with that number. It is clear that many *Culex* were counted in the laboratory but not in the smart trap. And that, on the other hand, the smart trap counted more *Aedes*. This cannot be due to predation. This indicated that smart traps have troubles in correctly identifying *Culex*. They seem to often identify *Culex* mosquitoes as *Aedes*, leading to an **overestimation of *Aedes***. The correlations are also low.

We then added the sex dimension (Figure 7).

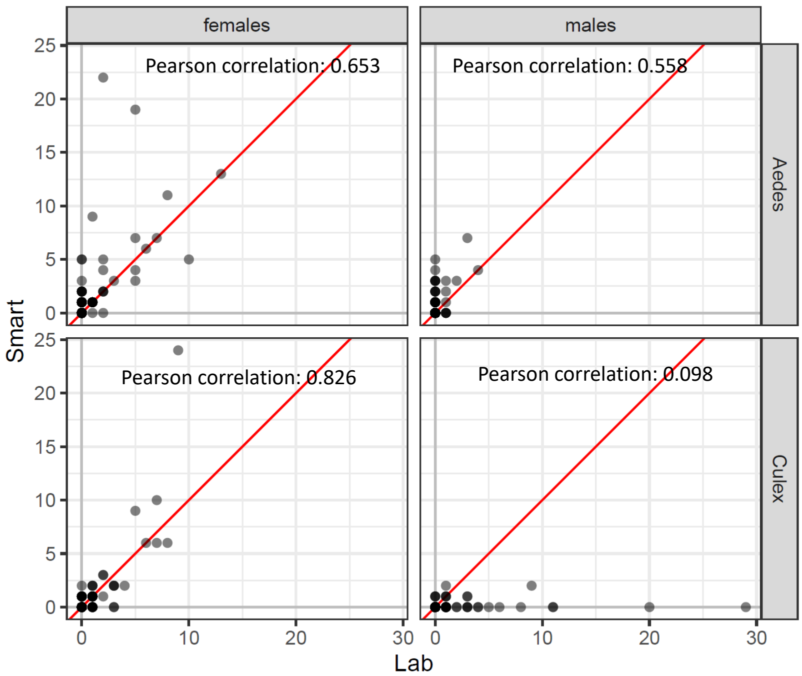


Figure 7. Scatter plots comparing smart-trap and laboratory counts for females (left) and males (right) *Aedes* (top) and *Culex* (bottom) genera.

The plots show that the smart traps often under detect *Culex* males, whereas *Aedes* females are over detected. Therefore, it would seem that the smart trap has more difficulty with males and classifies them as females. The correlations are generally low.

**Laboratory tests**

Because the field results revealed substantial accuracy issues in the smart trap classification and counting performance, we conducted controlled laboratory tests to further assess the device under standardized conditions. Two mosquito colonies were used: an *Aedes albopictus* colony maintained at SUPSI, and a *Culex pipiens* colony provided by the University of Zurich.

We tested four groups separately: *Ae. albopictus* females, *Ae. albopictus* males, *Cx. pipiens* females, and *Cx. pipiens* males. For each group, a defined number of individuals (see table below) was released into a cage containing a smart trap. The trap remained inside the cage for approximately 48 hours, or until no mosquitoes were left alive in the cage.

At the end of each trial, we counted the total number of mosquitoes recovered in the catch bag and compared this with the number recorded by the smart trap. The results are presented in the table below.

| **Species tested** | **Mosquitoes released** | **Mosquitoes in catch bag** | **Mosquitoes determined by the smart trap** | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Aedes* F | *Aedes* M | *Culex* F | *Culex* M | Total |
| *Ae. albopictus* females Colony 1 (Ticino) | 30 | 24 | 15 | 3 | 5 | 0 | 23 |
| *Ae. albopictus* males Colony 1 (Ticino) | 30 | 28 | 0 | 26 | 0 | 0 | 26 |
| *Cx. pipiens* females Colony 2 (Zurich) | 47 | 46 | 8 | 0 | 59! | 0 | 67! |
| *Cx. pipiens* males Colony 2 (Zurich) | 47 | 35 | 3 | 15 | 0 | 11 | 29 |

Only for *Ae. albopictus* males did the number of individuals recovered in the catch bag (26) match the number counted by the smart trap. Several *Ae. albopictus* females were misclassified as *Aedes* males or even as *Culex* females. Some *Cx. pipiens* males were identified as *Aedes* females, and many others as Aedes males. Strikingly, of the 47 *Cx. pipiens* females released, the smart trap recorded 59 *Culex* females, indicating that individual mosquitoes were counted multiple times.

According to the manufacturer, this over-counting occurs because *Culex* females can climb along the inner walls of the trap toward the sensor exit. As soon as they attempt to fly away, they are drawn back down by the suction of the fan, causing the same individual to pass through the sensor repeatedly and thus be counted more than once.

# 4. Conclusions

This study evaluated the performance of five smart traps deployed in the Canton of Geneva, complemented by controlled laboratory tests using colonies of *Aedes albopictus* and *Culex pipiens*.

Across both field and laboratory conditions, the results consistently revealed substantial limitations in the device's ability to accurately classify and count mosquitoes.

Field data showed poor agreement between machine-generated and human-determined counts, with high misclassification rates and inconsistent identification across sex–genus categories. The smart trap frequently misidentified *Culex* mosquitoes as *Aedes*, leading to a systematic overestimation of *Aedes* abundance, a critical issue for surveillance of invasive species. Errors were also common in sex determination, further reducing the reliability of the data.

Controlled laboratory tests confirmed these issues. Only *Ae. albopictus* males were counted correctly. All other groups exhibited substantial misclassification, and repeated counting of the same individuals was documented, particularly for *Cx. pipiens* females, which were counted more times than the number of individuals released. According to the manufacturer, *Culex* females may repeatedly climb toward the sensor and be re-drawn into the airflow, causing multiple detections of the same specimen.

Because of these inaccuracies, several planned analyses, such as evaluating the effects of mosquito abundance, sampling duration, seasonality, trap identity, or the stability of precision across environmental or operational conditions, could not be meaningfully performed. The data quality was simply insufficient to support such modelling.

A further limitation is structural: the smart trap is not capable of distinguishing species within the same genus. In regions where multiple *Aedes* or multiple *Culex* species co-occur, this poses a significant challenge. Under such circumstances, species-level surveillance, essential for public health decision-making, cannot be achieved with the current system. These constraints are particularly relevant in Switzerland, where multiple species of *Aedes* may be present.

Overall, the results indicate that, under Swiss field conditions, the current version of the smart trap system does not provide the level of accuracy required for reliable mosquito surveillance. While the concept of automated, real-time monitoring remains promising, substantial improvements in species recognition, sex determination, and counting algorithms are needed before the technology can be recommended for operational use.

At present, we cannot recommend using this tool for mosquito surveillance in Switzerland, including for surveillance and control activities in Geneva. Alternative, validated approaches should be considered until the Smart Trap system is significantly improved and better trained for local species and conditions.

The results were presented to BAG at the meeting of the Working Group (WG) on "Vectors" of the Subsidiary Body "One Health", held on 3 December 2025 in Mendrisio.

## 5. References

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# 6. Acknowledgements

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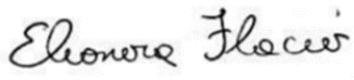

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