ALBIS: integrated system for risk-based surveillance of invasive mosquito Aedes albopictus

Milan P. Antonovic[1], Massimiliano Cannata[1], Andrea Danani[3], Lukas Engeler[2], Eleonora Flacio[2], Francesca Mangili[3], Damiana Ravasi[2], Daniele Strigaro[1], and Mauro Tonolla[2]

[1]**Institute of Earth science - SUPSI**
[2]**Laboratory of Applied Microbiology - SUPSI**
[3]**Dalle Molle Institute for Artificial Intelligence Studies - SUPSI**

Corresponding author:
First Author[1]

Email address: milan.antonovic@supsi.ch

ABSTRACT

According to predictions bases on a climate-driven large-scale model the areas surrounding Lake Léman and, to some extent, the Swiss Plateau are suitable for the spread of *Ae. albopictus* North of the Alps, while other areas in Switzerland (e.g., the city of Zürich) seem currently too cold in winter for the survival of eggs. However, this model does not take into account particular micro-climate conditions in urban areas where the specie thrives. Climate conditions in urban micro-habitats (in particular catch basins) increase the probability of the survival of diapausing eggs in the winter season favoring the colonization of new cities that were thought to be too cold for the survival of the eggs. Therefore, there is an urgent need for appropriate monitoring tools and risk-based surveillance of *Ae. albopictus* populations.
In 2018 a multidisciplinary group of researchers from the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) has joined launching the project ALBIS (Albopictus Integrated System). The designed system focuses on the monitoring of urban catch basins, primarily on micro-climate environmental sensing, data transmission, data acquisition and data dissemination. The gathered data are the input for an empirical machine learning model for the prediction of spatial and temporal distribution of the *Ae. albopictus*.
The first real time monitoring tests are in progress in the pilot area in the city of Lugano in the Canton Ticino. Fully functional prototypes have been engineered by the Institute of Earth Science in collaboration with a local electronics manufacturer (TECinvent) combined with the Open Source istSOS OGC Sensor Observation Service software for data acquisition and dissemination, and in the first tests cases have demonstrated good quality in terms of energy efficiency, data quality and data transmission reliability.
The first results demonstrated that temperature in catch basins can be different from outside temperature that is detected by traditional terrain measures: in February 2018 during a period of cold air temperature in Canton Ticino of down to -8℃, the prototype sensor monitoring the catch basins' wall surface shows temperatures up to 6℃ higher. Considering that one of the *Ae. albopictus* establishment thresholds is to have a mean January temperature of >0℃ to allow egg overwintering, taking into account this micro-climate environments could lead to more realistic predictions.

INTRODUCTION

In the 2000, anticipating the introduction of the invasive Asian tiger mosquito, *Ae. albopictus*, from Italy (Neteler et al., 2013; Knudsen et al., 1996), a working group for surveillance and control of the mosquitoes (Gruppo Cantonale di Lavoro Zanzare) was established in the Canton of Ticino by the Swiss local authorities. Since then, the working group (today managed by the Laboratory of Applied Microbiology, LMA-SUPSI) has monitored the population of *Ae. albopictus* using conventional ovitraps. *Ae. albopictus* is firmly established in urban areas of Canton Ticino since 2007 (Flacio et al., 2015). At the end of the 2017 more than 10K samples have been collected producing useful information to understand the diffusion of the insect. In 2018 a multidisciplinary group of researchers and scientists from the University of Applied Science of Southern Switzerland (SUPSI) has joined launching the project ALBIS (Albopictus Integrated System) with the aim of bringing a shift in the paradigm of data analysis and monitoring of the invasive Asian tiger mosquito Aedes albopictus by making data collection and analysis more automated, more dynamic and efficient. The ALBIS working group is formed by the Laboratory of Applied Microbiology (LMA) with his internationally recognized mosquito surveillance system, the Institute of Earth Science (IST) with expertise in the field of low cost non-conventional monitoring system and sensor data management and the Dalle Molle Institute for Artificial Intelligence (IDSIA) applying empirical machine learning models for spatial and temporal distribution analysis of *Ae. albopictus*.

The work-flow (Figure 1) consists in a phase of in-situ acquisition of data coming from real time micro-climate parameters (IST), egg counts from ovitraps and surroundings atmospheric conditions from weather stations. The resulting data is gathered and disseminated by the istSOS server and then, combined with geographical information systems, used by a machine learning model (IDSIA) that calculate the population distribution of the mosquitoes and produce maps of risk scenarios for diffusion of *Ae. albopictus* in Switzerland.

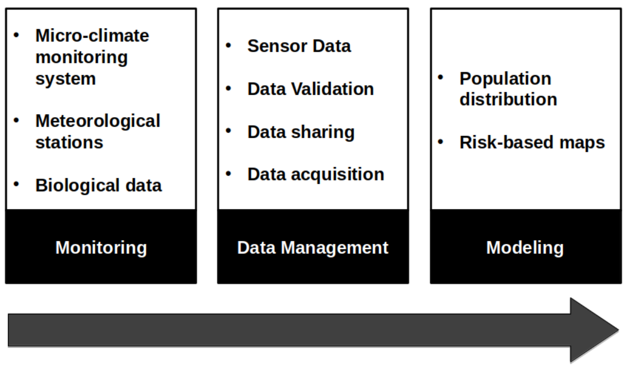

Figure 1. ALBIS work-flow for data collection and analysis

METHODS

At first the LMA group have been engaged in the identification of the most suitable places that represent the best use case location where to implement the ALBIS automated monitoring network. In Ticino, Lugano has been chosen as the pilot area mainly for practical reason due for proximity to SUPSI. In the northern part of Switzerland, Basel, Lausanne and Zürich have been chosen as indicative areas where *Ae. albopictus* could potentially have some probability to survive the winter season in warmer micro-climate conditions offered by catch basins (Ravasi et al., 2018). Meanwhile the Institute of Earth Science have been involved in the data management infrastructure and the selection and prototyping of the most suitable devices which shall meet the following requirements: low cost, low power consumption, long range data transmission and an adequate data quality of sensors measuring light intensity, air humidity, air pressure, wall humidity and water humidity. The choice for the in-situ hardware devices has fallen on LoPy4 (from Pycom Ltd. https://pycom.io), a 34.95 euro worth Micro-Python enabled development board that offers an open and modern programming language perfect for building sophisticated IoT (Internet of Things) infrastructures. Furthermore, LoPy devices integrate the LoRa/LoRaWAN specification (Alliance, 2017). A low power wide area network open standard, which uses license-free sub-gigahertz radio frequency bands offering a two way wireless transmission networking protocol. The sensors selected to acquire the data in the catch basins (Figure 2) are a BME280 (air humidity and pressure), two DS18B20 (for wall and water temperature) and a BH1750 (light intensity). Everything powered by a Li-ion battery with 4,000 mAh capacity.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018

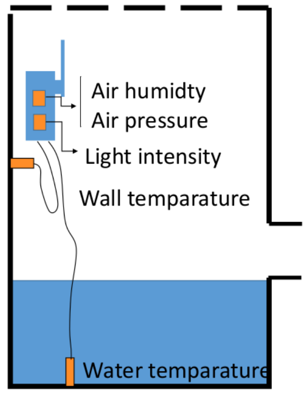

Figure 2. Monitoring requirements

The data management infrastructure relies on istSOS (Cannata et al., 2018), an Open Source software implementing the OGC Sensor Observation Service standard (Bröring et al., 2012). This software has reached version 3 (now in beta) and offer great flexibility, permitting an easy implementation of new plug-ins that can extend its base functionality adding more specific features.

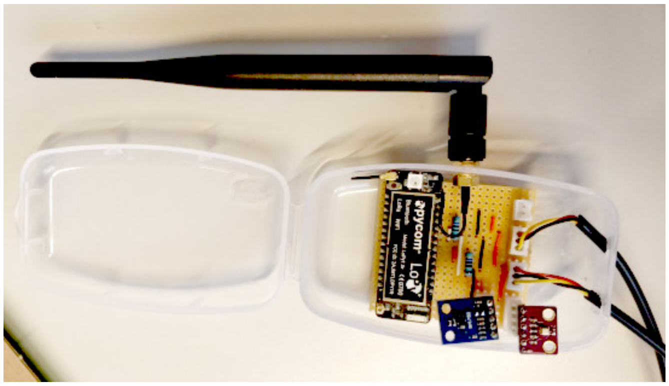

Figure 3. Prototype 1

After the first tests in laboratory (Figure 3), the collaboration with the local electronics manufacturer TECinvent (http://www.tinv.ch) has produced a printed circuit board (PCB) that permit the device assembly in a plug and play way speeding up the production and the maintenance of the devices (Figure 4).

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018

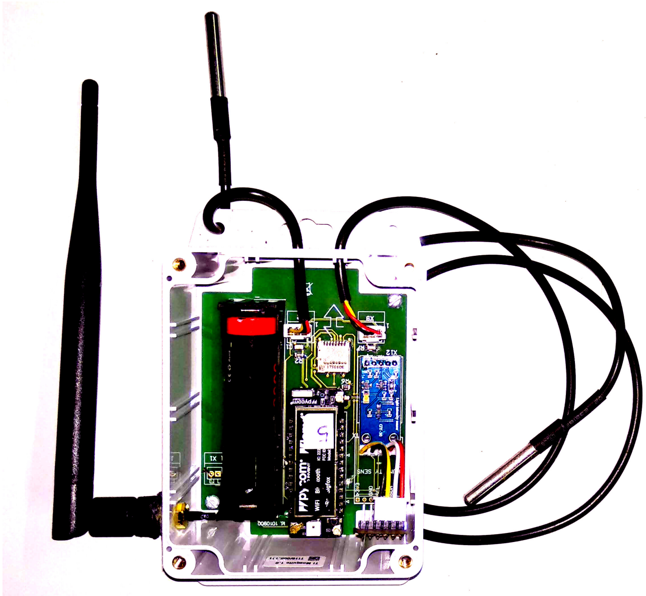

Figure 4. Prototype 2

Operationally all the deployed sensors power up every hour, take measurement from the surrounding micro-climate environment and send the data to a nearby, always on, LoRaWAN enabled gateway (attached to the electricity). This gateway is also assembled with a LoPy board and forwards the data through a conventional WiFi network or using an LTE connection.

All the data from the monitoring sensors converge over Internet towards the istSOS server, that has been enhanced with two new plug-ins that permit optimized LoRaWAN and MQTT communication between istSOS and the gateways. Furthermore all the historical data in CSV format coming from the ovitraps monitoring system have been imported in istSOS using Python scripting, and to facilitate the management of the LMA in the ovitraps monitoring process a specific web interface for istSOS3 has been developed as a plug-in.

RESULTS AND DISCUSSION

At this phase of the project, we have drafted some considerations regarding the cost of the device, data transmission, quality of sensors, power consumption and several months worth of data.

Cost of the devices: we have built two kind of device: the node and the getaway. In the case of nodes each deployed device is the same as the others nodes. The getaway instead can have two kind of configurations depending on the transmission protocol used to send the data to the istSOS server. The choice of this configuration depend on the availability of accessible nearby WiFi networks, otherwise a GPRS connection is required and the cost of the getaway is higher because the costs of SIM cards from mobile operators must be considered. In the next tables are listed the approximate cost of each type of device excluding shipment, assembly and tax. Table 1 lists the prices of each component of a single node.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018

Component	Quantity	Price in euros
LoPy4	1	30
Antenna LoRa	1	6.2
PCB Board	1	28
LiPo Battery 4000 mAh	1	3
BME280	1	4.4
BH1750	1	1.5
DS18B20	2	10.6
2GB SD card	1	3.5
Box	1	13
		Total in euros 100.20

Table 1. Approximative cost in euros of a single node

Table 2 list the prices of each component of a gateway with GPRS/LTE capabilities:

Component	Quantity	Price in euros
FiPy	1	44
Antenna LTE	1	7
Antenna LoRa	1	6.2
Expansion board	1	14.10
micro USB cable	1	3.50
USB adapter for AC/DC	1	1.8
Small box	1	15
		Total in euros 91.6

Table 2. Approximative cost in euros of a single getaway with GPRS/LTE connection

Table 3 list the prices of each component for a gateway with WiFi capabilities:

Component	Quantity	Price in euros
LoPy4	1	30
Antenna WiFi	1	6.2
Antenna LoRa	1	6.2
Expansion board	1	14.10
micro USB cable	1	3.50
USB adapter for AC/DC	1	1.8
Box	1	15
		Total in euros 76.80

Table 3. Approximative cost in euros of a single getaway with WiFi connection

Taking into account all the features offered by each device, the costs can be considered quite low, anyway on the occasions of large deployment the cost is not negligible, but keeping in mind that this is a first prototype, later iteration could decrease further the costs.

Data transmission: during the deployment of the first cluster of sensors in the pilot area of Lugano we found some issues using the LoRa protocol between sensors nodes and the gateway. In fact the presence of buildings and the positioning of the device under the ground surface in the catch basins was not negligible in terms of interferences. From an initial test phase in rural area that led to a promising

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018

range of 2 kilometers, in the city, the distance dropped to less then 100 meters. That aspect bring us to rethink the topology of the network, relocating the initial planned monitoring areas to facilitate the communication by selecting locations having minimal impact from buildings. Finally the gateway is located on a crossroad and the sensors are deployed along the branches (Figure 5).

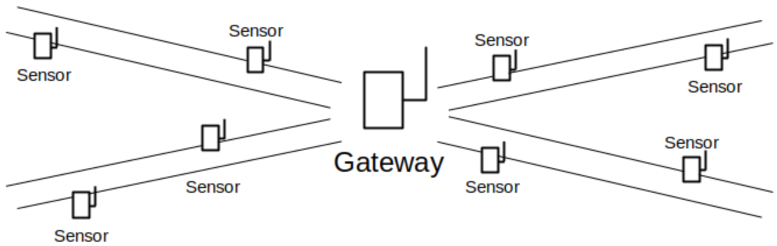

Figure 5. Sensor network topology

Quality of sensors: comparing the data quality of measured observations coming from low cost sensors with those produced by a professional meteorological station demonstrated a good level of precision with a mean error of +/-0.26°C.

Power consumption: the first test done with the sensors, powering up the node every 30 minutes and then put it in hibernation, have demonstrated a very good efficiency with more then 2 months of autonomy on a single charge with a 4,000 mAh battery.

Collected data: during February 2018 data analysis has shown that temperature in catch basins can be different from outside temperature that is detected by traditional measures (either indirect like satellite surface temperature or direct like weather station): during a period of cold air temperature, with records from official hydro-met station of Canton Ticino registering up to -8°C, temperatures from the prototype sensor registered in the catch basins' wall surface (the preferred diapausing eggs location) shows temperatures up to 6°C higher. Considering that one of the *Ae. albopictus* establishment thresholds is to have a mean January temperature of >0°C to permit egg overwintering, observing this micro-climate could lead to more realistic prediction.

FUTURE WORKS

In the next months we are planning to build and deploy a hundred of nodes in the cities of Basel, Lausanne and Zürich. In particular we will focus on the data quality and the reliability of the web services. Which means garantee constant time series of good data quality.

REFERENCES

Alliance, L. (2017). Lora alliance technology. *available at: www. lora-alliance. org/What-Is-LoRa/Technology*.

Bröring, A., Stasch, C., and Echterhoff, J. (2012). Ogc sensor observation service interface standard. *Open Geospatial Consortium Interface Standard*, pages 12–006.

Cannata, M., Antonovic, M., Strigaro, D., and Cardoso, M. (2018). istsos version 3. In *Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings*, volume 18, page 5.

Flacio, E., Engeler, L., Tonolla, M., Lüthy, P., and Patocchi, N. (2015). Strategies of a thirteen year surveillance programme on aedes albopictus (stegomyia albopicta) in southern switzerland. *Parasites & vectors*, 8(1):208.

Knudsen, A., Romi, R., and Majori, G. (1996). Occurrence and spread in italy of aedes albopictus, with implications for its introduction into other parts of europe. *Journal of the American Mosquito Control Association*, 12(2 Pt 1):177–183.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018

Neteler, M., Metz, M., Rocchini, D., Rizzoli, A., Flacio, E., Engeler, L., Guidi, V., Lüthy, P., and Tonolla, M. (2013). Is switzerland suitable for the invasion of aedes albopictus? *PLoS One*, 8(12):e82090.

Ravasi, D., Guidi, V., Flacio, E., Lüthy, P., Perron, K., Lüdin, S., and Tonolla, M. (2018). Investigation of temperature conditions in swiss urban and suburban microhabitats for the overwintering suitability of diapausing aedes albopictus eggs. *Parasites & vectors*, 11(1):212.

PeerJ Preprints | https://doi.org/10.7287/peerj.preprints.27251v1 | CC BY 4.0 Open Access | rec: 3 Oct 2018, publ: 3 Oct 2018