Citizen Science: A Gateway for Innovation in Disease-carrying Mosquitoes Management?

Frederic Bartumeus [1,2,3,*], Aitana Oltra [1,2], John R.B. Palmer [4]

1 Centre d'Estudis Avançats de Blanes (CEAB-CSIC). Blanes Girona, Spain.

2 CREAF, Cerdanyola del Vallès, Spain.

3 ICREA, Institut Català de Recerca i Estudis Avançats, . Barcelona, Spain.

4 Universitat Pompeu Fabra., Barcelona, Spain.

*Correspondence: fbartu@ceab.csic.es (F. Bartumeus).

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Abstract

Traditional methods for tracking disease-carrying mosquitoes are hitting budget constraints as the scales over which they must be implemented grow exponentially. Citizen science offers a novel solution to this problem but requires new models of innovation in the public health sector.

Main text

From traditional surveillance to citizen science

To control disease vector mosquitoes, public health agencies need to know where they are. Traditional surveillance methods like female oviposition traps are expensive to implement over large areas because they depend on labor from professional scientists or practitioners. Large-scale surveillance, however, is necessary because many disease-vectors are invasive species that spread rapidly, with "jumpy" invasion patterns causing them to frequently appear in unexpected places, far from their known ranges. This presents a problem for public health, particularly if the local entities in charge of surveillance have budget constraints. Surveillance costs quickly surpass budgets as invasive mosquitoes spread across territory. The situation becomes worse as the mosquitoes cross jurisdictional boundaries, requiring horizontal and vertical coordination among government agencies and other actors. Greater public participation, in the form of citizen science, offers a possible solution to this problem.

In the context of vector control, public participation is not a new phenomenon. In fact, it had been through the public that invasive mosquitoes were first detected in many regions, with entomologists deploying traditional methods in response to citizens' observations, e.g. [1, 2].

The difference is that in recent years, public participation has been formalized through specific citizen science programs which have been expanding and changing in important ways as citizens become networked on massive scales by the Internet, inexpensive mobile phones with powerful sensor arrays, and other technologies [3].

Current citizen science mosquito programs encourage involve civil society in a wide range of aspects, including cataloguing mosquito species biodiversity, assessing mosquito nuisance and social impact in cities (e.g. BiteBytes, Zanzamapp), adding real time information for daily mosquito population management (e.g. Mosquito Alert), and mapping mosquito breeding sites (e.g. Mosquito Habitat Mapper). Methodological approaches involve the use of apps, the collection of data through the internet, and even sending specimens by postmail, all on previously unimaginable scales. Importantly, most of the programs have in common a strong educational and awareness component, which is key to reducing disease risk and controlling vector species in private areas (e.g. backyards). Outcomes of these initiatives are as diverse as their goals and methods. For example, in The Netherlands the citizen science project Muggenradar has been used as an effective method for specimen collection to clarify the distribution of the *Cx. pipiens* biotypes [4]. In Germany, Mückenatlas has proven to be effective at detecting national changes in the mosquito fauna [5], and in Spain, Mosquito Alert has provided a comprehensive picture of the tiger mosquito distribution and helped to illuminate patterns of dispersal by car [6]. In the next section, we briefly explain the history of Mosquito Alert and how it is driving innovation in public health decision making and daily vector management.

Mosquito Alert: a case study in Spain

When the authors started analyzing the Asian tiger mosquito (*Aedes albopictus*) invasion in Spain [7,8] several years ago as part of our research we realized that surveillance covered certain areas near the places where these mosquitoes had been detected, but the spatial and temporal coverage was spotty and clearly incomplete. Surveillance ended or was reduced in some places once the species was first discovered, or as a consequence of the economic crisis, even as evidence was building that the mosquito was spreading rapidly along the coast and towards the interior. The fact that tiger mosquitoes are relatively well known by local populations due to its aggressiveness and nuisance and that the species is relatively easy to identify suggested that there might be a role for public participation in these efforts. This led us to start exploring citizen science as a solution, developing Mosquito Alert (www.mosquitoalert.com) in 2013 as a small pilot project [9], with a platform initially aimed at facilitating the reporting of tiger mosquitoes first at schools (2013), and later on by the general public (2014-onwards), using mobile phones for researchers to use the data, build distribution maps and raise awareness among the population.

Open and participatory science leds research projects to evolve in ways that one cannot anticipate at the start. At Mosquito Alert, it quickly became clear that the participants wanted to know that their reports were actually leading to pest control actions. Therefore, we started to encourage public health agencies to get involved in the project, something that required the

development of a mechanism to ensure the reliability of the reports in an almost real time pace. We added an expert validation component, whereby every photograph sent by a citizen scientist is reviewed and scored by a team of entomologists and a set of customized management portals to help public health actors react on citizen data in real time (Figure 1).

The project continued to evolve, and we are now working to better integrate Mosquito Alert within the public health system and national vector control plan at different levels of government across Spain. We are doing so by tailoring specific web portals, alerts, and data visualization tools to agency needs, including the possibility of communicating directly with citizen scientists, and new systems for visualizing, sharing and exploiting disease risk information in near-real time.

Citizen science and big data: towards open innovation models for public health

There is increasing evidence that combining citizen scientist data with other sources of information significantly improves our knowledge in a given area [1,2,7,8,10,11]. In addition, our recent work [12] shows that, once we adjust for sampling biases associated to smartphone-collected information, citizen science data has almost the same quality and predictive power as that obtained from traditional surveillance. Clearly, combining citizen data with other data sources, adds statistical robustness and offers a solid basis for long-term, cost-effective management strategies [e.g. 6,12].

If combined with big data solutions [13], citizen science promises to augment information already available from public health sources (authoritative data) and provide it quickly and efficiently to mitigate risk and reduce health threats. Importantly, in the context of vector-borne diseases, citizen science is not only a massive education and awareness tool for civil society, but it can lead to new models of open government and innovation [14]. According to such models, an invention becomes a full-scale innovation when adopted by the many stakeholders (citizen, government, academia, private sector), which actively transform and add value to it [14]. In other words, innovation happens when a customer becomes a co-creator of value, an active subject of the innovation process, and is not merely a passive object.

The real question is whether the government (e.g. public health agencies or public mosquito control services) or the private sector (e.g. pest control companies) are willing to adopt such inventions [14,15], and whether academics are prepared for transferring knowledge and serve scientific outputs at the speed required in vector control plans as to generate effective control actions and change public health policies. It is important to note that Europe is traditionally stronger in research output and weaker in innovation take-up (i.e., adoption). Developing citizen science systems for the surveillance and control of disease-carrying mosquitoes requires of technological breakthroughs but also the alignment of interests, openness, and investment and collaboration across many stakeholders. Indeed, long-term sustainability can only be achieved if public administrations at different levels, become active subjects of the innovation process, and find ways to incorporate citizen science and novel technologies into national vector planning and

strategy. If this does not happen, these systems are at risk of becoming simple “millennial” academic exercises that can generate some amount of scientific production and then die.

From regional initiatives to globalized solutions

In parallel, and following the vector control roadmap laid out recently by the World Health Organization [16], the other challenge is to exploit the inherently scalable nature of Internet networked citizen science to offer an open, global toolkit that can aid in the fight against mosquito-borne diseases at the global scale. The potential exists but its implementation requires the generation of data and method standards across different projects, as well as developing modular projects were code and data can be easily shared and reused in other countries facilitating structural interoperability and shared global knowledge.

In April 2017 a workshop sponsored by UN Environment and organised by the Wilson International Center for Scholars’ Science and Technology Innovation Program (STIP), and the European Citizen Science Association (ECSA) launched a Global Mosquito Alert Consortium (GMAC), bringing together experts and heads of vector-mosquito citizen science projects from around the world. The GMAC is now pooling expertise to design a set of tools and best practice guides that can be drawn on and customized to local needs in any area facing a disease-vector mosquito problem.

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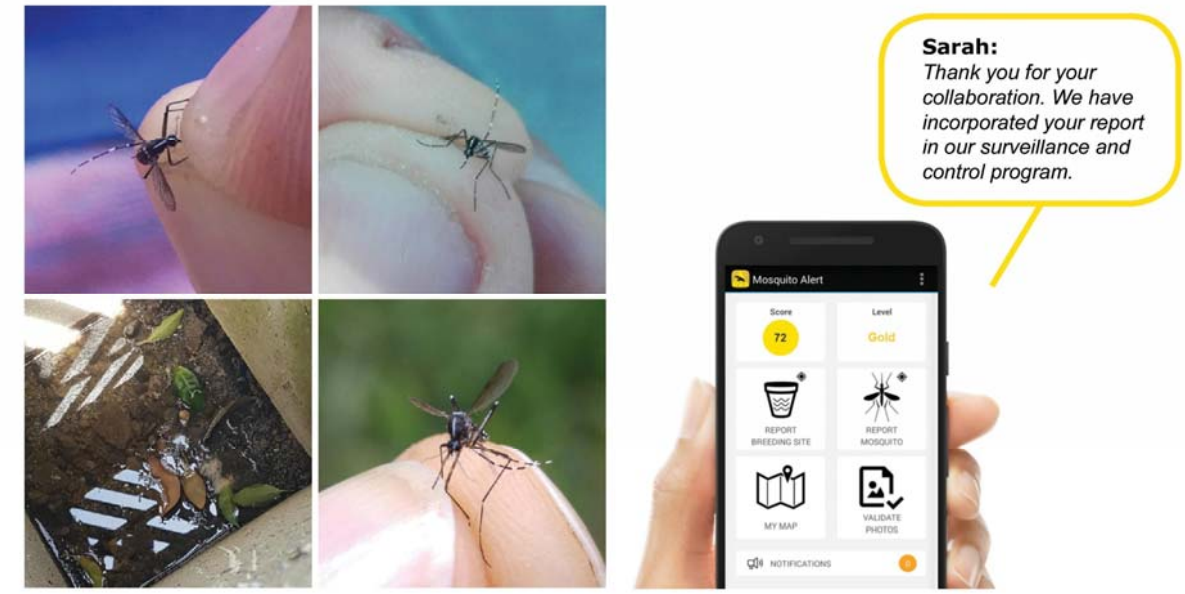
TEXT BOX

A day in the life of Mosquito Alert

Roger, a student in Barcelona, downloads Mosquito Alert. At a city garden, he notices a mosquito that has just bitten him and now lies dead in the palm of his hand. The application guides him through the process of determining the species and helps him send a geo-located report with a photograph of what he has found.

Sarah is responsible for mosquito management in Barcelona. Together with her team, she validates entering photographs and concludes that Roger has found an *Ae. albopictus*. Reports from citizens are combined with spatio-temporal estimates of sampling effort based on optional, anonymized background tracking of participants' locations and fed into a webmap that is presented to the general public and to Sara's public health agency.

After evaluating Roger's picture, Sarah's team prioritizes the reported garden for surveillance. They find mosquito larvae and treat their breeding sites. The team also distributes educational material in the neighbourhood and suggests local schools to joint an educational programme based on citizen science tools. Back at her office, Sarah thanks Roger via the Mosquito Alert app, and invites him to keep on feeding new information into the system.



Left: Tiger mosquito and breeding site pictures taken by anonymous participants (e.g. Roger) using the Mosquito Alert platform. (Mosquito Alert CC-by). **Right:** Mosquito Alert app with notification sent by local authorities (e.g. Sarah) to a participant.