

Citizen science set in motion: DIY light traps for phlebotomine sand flies

Rosa Gálvez^{a,*}, Marcos López de Felipe^b, Felipe Yebes^c

^a Department of Specific Didactics, School of Education and Teacher Training, Universidad Autónoma de Madrid, Madrid, Spain

^b Laboratorios Lókimica, Research and Development Department (R&D), Valencia, Spain

^c High-School Joaquín Rodrigo, Madrid, Spain

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ABSTRACT

Phlebotomine sand flies are vectors of various diseases such as leishmaniasis making them a public health concern worldwide. To increase the tools available for the study of sand flies, we developed do it yourself (DIY) light traps made mainly from recycled materials and tested their effectiveness in the field. This new model is named Flebocollect light trap. In this report we describe how the DIY light traps are prepared and illustrate the process with a short video. Lowering costs makes this resource available for citizen science and educational projects, and for research groups with a low budget such as those in developing countries. Our preliminary results showed a capture rate increase of 37 % of DIY light traps over commercial CDC, although no statistical evidence has been obtained.

1. Introduction

Phlebotomine sand flies (Diptera, Psychodidae) are small insects that transmit leishmaniasis to humans and other animals causing an estimated 30,000 deaths each year worldwide (Kamhawi, 2017). Besides leishmaniasis, there are other relevant sand fly-borne diseases such as that caused by the sand fly fever Toscana virus (TOSV, genus *Phlebovirus*, family *Phenuiviridae*), present in the Mediterranean Basin, or Carrion's disease caused by *Bartonella bacilliformis* in the Andean region (Ready, 2013; Moriconi et al., 2017; Garcia San Miguel et al., 2020). In effect, the monitoring and control of sand flies is an essential public and animal health issue.

One of the most used approaches to monitoring phlebotomines is the use of CDC (Centers for Disease Control and prevention) light traps which may be considered a gold standard method. The trap body is an acrylic tube containing an incandescent light bulb (which attracts sand flies), a motor, and a fan (which sucks attracted sand flies and prevents the escape of collected specimens). An insect collection cage made of fine nylon netting is connected to the trap body to store captured flying insects. The light source of this classic model has been subject to modification and newer models have LED lights to reduce energy consumption and extend battery life (Hoel et al., 2007; Fernandez et al., 2015; Silva et al., 2015; Rodríguez-Rojas et al., 2016; Gaglio et al., 2017, 2018; da Silva et al., 2019; Silva et al., 2020). Further benefits are that the color of the LED lights can be easily changed. Moreover, the effects

of factors such as luminous intensity (Lima-Neto et al., 2018) or the influence of moonlight (da Silva et al., 2020) can be assessed as these could affect how many phlebotomines are captured.

More recently, an open-source 3D-printed mosquito trap has been developed which is of lower cost than a CDC light trap (Hoshi et al., 2019). Such innovations are ideal tools for citizen science whereby any person can take part in scientific research projects (Silvertown, 2009). The benefits of citizen science are numerous. Above all, it offers massive data collection that would otherwise be impossible to carry out by a few specialized scientists. This is particularly important in ecological studies that require an intense sampling effort across a large area. In addition, it should be noted that citizen science is in vogue in the field of entomology (Pelacho et al., 2020). An example is the urban butterfly observatory eBMS (European Butterfly Monitoring Schemes) present in more than twenty-five countries in Europe. In this project, anyone who wants to volunteer can do so and will be trained to identify different species with the help of a team of experts who screen all the tasks undertaken (eBMS 2021). Citizen science is also used to identify mosquito species in different campaigns across Europe such as "Mueckenatlas" in Germany (Werner et al., 2020) or "Mosquito Alert" in Spain (MosquitoAlert, 2017). In the case of Spain, this system has been especially successful in the last few years and has led to the identification of the introduced vector species *Aedes japonicus* through data provided by users of the mobile app of this project (Eritja et al., 2019, 2021). Lastly, recently it has been published that volunteer citizens were enrolled for

* Corresponding author.

E-mail address: rosa.galvez@uam.es (R. Gálvez).

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monitoring the malaria vectors in Ruhuha, Rwanda using a handmade trap (Murindahabi et al., 2021) which consists of a plastic bottle wrapped with a black scotch tape, filled with yeast and sugar, and a torch that was hung above the opening of the trap (Asingizwe et al., 2019).

We would like to emphasize that citizen science projects focusing on medical entomology can also be used as teaching tools, as interactions between vectors and public health offer many opportunities in primary and secondary education (Matthews et al., 1997). An example is the teaching project "FleboCollect", which focuses on student participation in research activities aimed at contributing to scientific knowledge through citizen science (Gálvez et al., 2019). This project has led to the development of our DIY light trap as a tool for research into sand flies. Lowering costs makes this resource available for citizen science and for research groups with a low budget such as those in developing countries. Other strategies that can be implemented in underdeveloped regions with limited pest management resources, such as the use of homemade cheese infusions or the use of used coffee grounds as larvicide for use in integrated mosquito control programs, are being studied (Drago et al., 2021; Peach et al., 2021).

In this report we describe how the DIY light traps are prepared and illustrate the process with a short video available as Supplementary data. We also analyze the results of a preliminary study designed to test the effectiveness of these traps in comparison with commercial CDC light traps.

2. Material and methods

2.1. Study background and materials

FleboCollect, led by the Spanish partner of the Universidad Autónoma de Madrid, is a subproject of the BRITEC (Bringing Research Into The Classroom) research project funded by the European Union in the Erasmus + KA2 Program from 2018 to 2021 under Key action 2 (Cooperation for Innovation and Exchange of Good Practices).

Here we describe our work prior to implementation of the set of FleboCollect activities designed for schools (Gálvez et al., 2019). The working group met in a publicly funded citizen laboratory in Madrid (Spain), Medialab Prado, every 2 or 3 weeks from May to December 2019 (13 meetings of two and a half hours each, with an average participation of 6–7 people). The multidisciplinary work was carried out in the Fablab (Fabrication Lab) with the aim of developing a DIY light trap model with recycled and readily available materials (MediaLab Prado, 2021). A total of 21 people participated at different moments in the various meetings that were held. The knowledge profiles of the participants were diverse: physicians, veterinarians, biologists, fine arts graduates, university teachers of non-scientific disciplines, high-school teachers of biology and technology, biology and veterinary students, etc. This multidisciplinary enriched the approach to this project. A step-by-step manual is openly provided so that anyone can manufacture the DIY light trap model in three steps: 1) preparing the suction tunnel, 2) setting up the electronic circuit, and 3) fitting the collection bag.

The materials needed are a large milk/juice tetra brick, pen marker, a ruler, a recycled computer fan, a screwdriver, scissors, black duct tape, a cereal box, power supply (the minimum power supply needed for these components is 12v, 3.5 A), cutter, pliers, PCB board prototype, 470 ohms resistor, 5 mm yellow LED light (3.0–3.2 V), PCB terminal blocks,

welder, welding wire, wedding veil fabric, sewing thread, pins, needles, rubber band and a takeaway food plastic recipient. General information of the recycled computer fans is specified below (Table 1).

2.2. Study area, sand fly identification and preliminary data analysis

Once the first prototypes were prepared, its effectiveness was tested under field conditions. To test the traps, we placed them weekly in July 2020 (4 study nights: July 11th, 16th, 22nd and 29th) in the Municipal Animal Shelter in Torreldones, Madrid (Spain). We chose July because it is the month in which the highest abundance of sand flies is detected in the area (Gálvez et al., 2010). The study area is characterized by having a semi-arid climate, with dry, hot summers. The animal shelter is in the periphery of an urban area and close to a holm oak wood (*Quercus ilex*) on sandy soil. The species found in this area are mainly *Phlebotomus perniciosus* and *Sergentomyia minuta*, and occasionally *P. sergenti* (Gálvez et al., 2010; Prieto et al., 2021). We used three miniature CDC light traps (BioQuip #2836BQ-6VDC) with an incandescent light source (c1, c2 and c3) as controls and four DIY traps with yellow LEDs as the test models (t1, t2, t3 and t4). The traps were set up from 8 pm to 8 a.m. on the following morning, which is when phlebotomine adults are active. They were placed at a constant height of 0.5 m above the ground, and 0.75 m apart from each other since the maximum distance of the attraction of the light appears to be 2 m in *P. ariasi* (Killick-Kendrick et al., 1985) and 6 m in *Litzomyia longipalpis* (Valenta et al., 1995). In this way, sand flies will be exposed to both types of traps (DIY and CDC) and will be sucked into the trap that attracted them the most. During each study night, the traps were interchanged to eliminate the position effect (Fig. 1).

In the morning, the insects were recovered from each trap and preserved in ethanol 70 % until their taxonomic identification (Tello Fierro et al., 2014). The density of sand fly captures per trap (where "t" test and "c" control) was expressed as individuals captured per sampling night and was separated by sex and species (Table available as Supplementary data). From the sand fly density value obtained for each of the three CDC traps during each sampling night (c1, c2 and c3), the average was calculated for the controls (C):

$$\text{Average number captured sand flies}(C) = \frac{c1 + c2 + c3}{3}$$

The DIY/CDC ratio was then calculated as the number of phlebotomine sand flies captured using each DIY trap ("t") expressed in relation to C for each sampling night to compare the efficacy of captures between both types of traps. Accordingly, if this ratio was equal to or around one this meant that the DIY trap was as effective at trapping sand flies as the CDC trap.

$$DIY / CDC = \frac{t}{C}$$

A Mann-Whitney *U* test was employed to assess whether DIY/CDC ratios differed by sex and/or species. For all statistical tests we used the software RStudio versión 2021.9.0.351 (RStudio Team, 2021). Significance was set at $p < 0.05$.

3. Results

3.1. Building the DIY sand fly traps

In this section, we describe how the sand fly traps are prepared

Table 1

Detailed electronic specifics of the recycled computer fans as specified by the different providers.

DIY Trap	Brand name	Model	Size (cm)	Voltage (V)	Amperage (A)	Number of blades	Speed (rpm)	Air Flow (CFM; m ³ /h)
t1	Cooler Master	MGT7012MR-A25	7 × 7 × 2.5	12	0.17	7	3000	44.123
t2	Scythe	SY1225SL 12M	11.9 × 11.9 × 2.5	12	0.26	9	1200	116.449
t3	Delta Electronics, INC	AFC 1212DE	12 × 12 × 3.8	12	1.60	7	3900	251.452
t4	Tacens Pro	14025SL	12 × 12 × 2.5	12	0.30	11	800	61.844

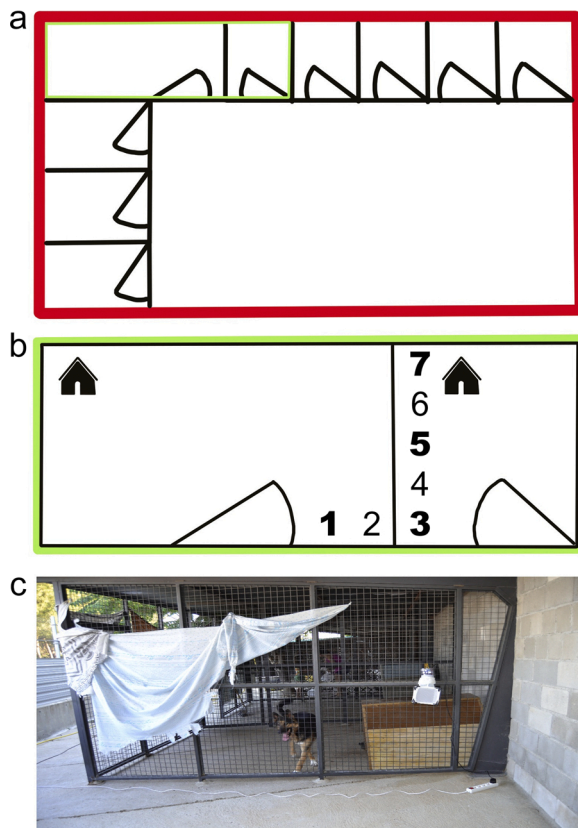


Fig. 1. Kennels and trap rotation system set up in the Municipal Animal Shelter. a, Locations of the different kennels in the shelter; b, Positions of the DIY traps highlighted in bold (other positions were reserved for control traps); c, Photo showing one of the kennels.

(Fig. 2). Detailed instructions are summarized in two videos available in the Appendix A. Supplementary data.

3.2. Suction tunnel

First, we need to obtain a computer fan by taking apart the computer tower with the help of a screwdriver. Once the fan is recovered, all the cables except the power suppliers, which are usually red and black, need

to be cut. The body of the trap acts as a suction tunnel for the sand flies. For the tunnel, a large milk/juice tetra brick is needed. The tetra brick should be cut to make a square out of the cardboard in the middle. Draw a vertical line in the center of each side and make four cuts to obtain 4 pieces that will be the corners of the tunnel. The tunnel needs to be adapted to the size of the fan. Tape each of the four pieces of cardboard to the corners of the fan making sure that the power cables remain outside the tunnel. To make the sides of the tunnel, we must place more duct tape on the outside to complete the uncovered parts. The sides of the suction tunnel should be reinforced on the inside with pieces of cardboard from a cereal box cut to size and covered with more duct tape. Repeat the same process on the other side of the fan, so that the fan is in the center of the suction tunnel. Now, it is time to test the fan using a power supply (12v, 3.5A). This will reveal the side of the fan where the air is sucked in, to be placed on top of the trap. We then drill a hole on each side of the suction tunnel so that it can be threaded with a piece of string to hang the trap.

3.3. Electronic circuit

Next, a LED circuit needs to be prepared and installed on top of the fan to attract the phlebotomines. With the help of pliers and a cutter, we cut a PCB board prototype into a small piece to make the electronic circuit. We need to weld the components of the LED circuit (470 ohms resistor, 5 mm yellow LED and PCB terminal blocks) onto the PCB board prototype as shown in Fig. 3. To install the circuit, we must connect the fan and terminal wire for power supply (12v, 3.5A) to the PCB terminal blocks. To fix the light on top of the fan we can use some duct tape. We must consider the polarity of power supply to obtain the correct suction effect. The power supply can be a recycled small electronic device from laptop, videogame consoles.... Before use, it is advisable to check the voltage and electric power.

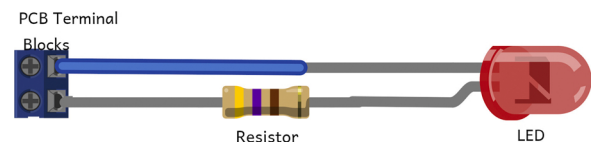


Fig. 3. Circuit components.

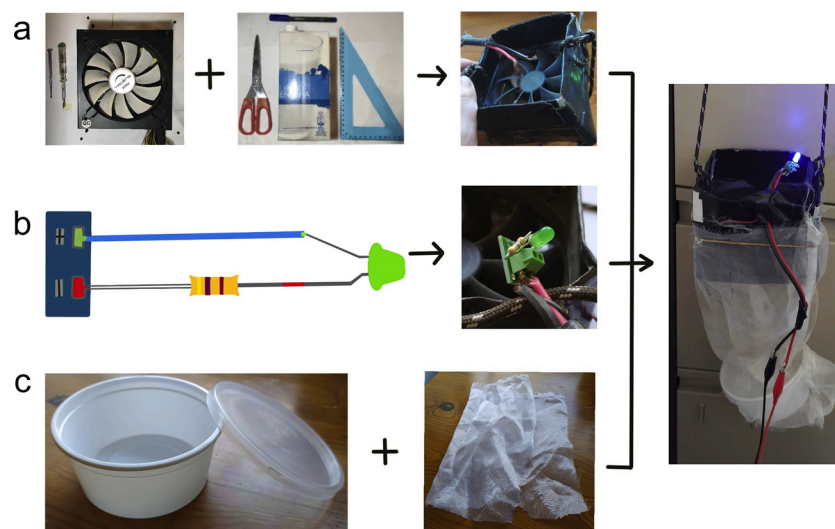


Fig. 2. Infography summarising the steps needed to make the DIY phlebotomine traps. a, preparing the suction tunnel; b, setting up the electronic circuit; c, fitting the collection bag.

3.4. Collection bag

Finally, we can prepare the collection bag for the captured phlebotomine sand flies to be attached to the bottom of the suction tunnel. A wedding veil (pore size less than 0.4 mm) is sewn to obtain a cylinder approximately 0.35 m long and whose perimeter fits the lower part of the suction tunnel. With the help of a rubber band, the collection bag is secured. Next, a hole is made in the lid of a food takeaway plastic recipient. The lower end of the cloth cylinder is then inserted through the hole and the container is closed while part of the veil is left outside.

3.5. Preliminary results

In total, 425 phlebotomine sand flies were captured in the four sampling sessions. Seven individuals were not identified as they were damaged and lacked the structures necessary for taxonomic classification. All damaged specimens ($n = 7$) were found in DIY light traps: 1 from t1 and 6 from t3. Of three species identified, *Phlebotomus perniciosus* was the most abundant ($n = 267$), followed by *Sergentomyia minuta* ($n = 146$) and *P. sergenti* ($n = 5$). Detailed results are summarized in a Table as Supplementary data.

Based on the results, a Mann-Whitney U test was used to assess whether DIY/CDC ratios differed according to species or sex (Table 2).

Although no differences were observed between the DIY and control traps, the former returned higher capture rates than the CDC control traps. Based on DIY/CDC ratios, we assessed the proportions of captured species of each sex (Table 3). These results revealed higher catch rates stratified by sex and species for the DIY than control CDC traps, as this ratio was in all cases higher than one. Thus, preliminarily, our in-house traps captured 37 % more sand flies compared to the commercial traps and higher numbers of males were detected.

4. Discussion and conclusions

To our knowledge, this is the first study to propose the construction of DIY light traps using mainly recycled materials to capture phlebotomine sand flies. Another homemade phlebotomine light trap designed by another research group employed one disposable plastic screw-top jar and a plastic hair roller (Fernandez et al., 2015). What sets us apart from these efforts is our philosophy of reusing old materials.

Flebocollect model light trap is inexpensive and easy to manufacture. The construction of our traps was approached in such a way that very few non-recycled materials are needed. It could be that the components needed to assemble the LED light circuit, or the veil fabric needed to make the collection bag may have to be purchased. These are nevertheless low-cost materials. It is worth noting that to carry out the whole process, it is important to have access to the tools detailed in the section 2.1. Study background and materials. Thus, to reduce costs it is ideal to work in open collaborative spaces like Medialab Prado that allows for the use of such specific tools (MediaLab Prado, 2021). In addition, working in multidisciplinary groups, as detailed in this proposal, will contribute to enriching the results of any project. Finally, to follow the video tutorials in the Appendix A. Supplementary data, and explanations in the text, no advanced knowledge of electronics is required, and

Table 2

Mann-Whitney U test comparison of DIY/CDC by species and sex (p -value < 0.05). Pp = *P. perniciosus*; Sm = *S. minuta*.

DIY/CDC	Mann-Whitney U	P
Pp male	58.5	0.150
Pp female	81.0	0.744
Sm male	73.5	0.483
Sm female	74.0	0.497
Total male	63.5	0.234
Total female	79.5	0.689
Total	66.0	0.288

Table 3

Descriptive comparison of DIY/CDC by species and sex and percentage efficacy improvements for the DIY traps compared to the control traps. Pp = *P. perniciosus*; Sm = *S. minuta*.

DIY/CDC ratio		Efficacy improvement %
Pp male	1.556	56%
Pp female	1.091	1%
Sm male	1.776	78%
Sm female	1.130	13%
Total male	1.522	52%
Total female	1.110	11%
Total	1.374	37 %

anyone can design their own DIY trap.

By sharing trap designs openly with any researcher, as other authors have done with 3D-printed traps to capture mosquitoes (Hoshi et al., 2019), we wanted to contribute to entomological field studies worldwide, focusing on the use of this method not only in scientific research but also in vector control campaigns including educational projects or citizen science, among others.

While no significant differences were detected between the DIY and control CDC traps, higher capture rates were obtained, and also larger numbers of males were captured. Our results consisted of a higher capture rate than the CDC control traps, mainly in males but also in females of both *P. perniciosus* and *S. minuta*. Since these are preliminary results, future fieldwork will need to confirm and clarify the gender bias observed here. We also would like to address the deterioration effect seen in seven out of the 432 captured phlebotomine sand flies (1.62 % of specimens), as they had all been captured in DIY light trap (specially by t3, six of the seven). We do not consider the deterioration effect a result of the light trap design, because no damage was seen in traps t2 or t4 during the whole experiment. We then think that the resulted damage by t3 was due to a higher number of rpm of the fan and a resulted higher wind force. This is the consequence of a higher power by the t3's fan (12 V; 1.60A) compared to that of the rest of traps (around 12 V; 0.30A) (see Table 1).

Although no differences were seen, an increase in the capture rate of 37 % was observed. We consider this to be due mainly to the light source of the traps as well as to the trap design. LED-light emitting sources had been pointed out in the past as to be less affected by moonlight effect on capture rates compared to traditional halogen bulbs (da Silva et al., 2020). Also, the structure of the traps could influence the trapping efficiency observed between the two traps models. CDC commercial light traps' suction tunnels are clear, where the light can directly go through. In contrast, Flebocollect light trap model's suction tunnel is opaque, focusing light only in the upper opening of the trap. As a sole source of light is obtained, all attracted phlebotomine sand flies would be sucked into the contention net, increasing the trapping efficiency. This hypothesis should be address in future studies to increase the efficiency of this trapping systems.

Anyhow, prior to any future employment of this traps, after construction, a standardization procedure should be performed for comparing capture rates among traps. This would enable a wider use of this traps by different researchers and be able to share and compare results. We consider that the main variables concerning the capture rates are: the fan's size, rpms, number of blades and the wavelength and brightness of the color light source.

The use of light emitting diodes instead of incandescent light bulbs will make it possible to assess other variables such as the effects of light color. We would also recommend more testing to study the efficiency of these traps and to examine individual variations between different DIY traps.

The use of recycled materials is important not only to cut production costs but also to ensure the traps construction are sustainable and environmentally friendly. Given the present climate change scenario, the reuse of materials that would otherwise be discarded is essential for

protecting our ecosystems (IPCC, 2007). We consider that this project is a clear example of the great reach that citizen science can have in the field of medical and veterinary entomology when put into action (Pelacho et al., 2020). Although, to be able to obtain results with scientific value, all citizen science projects should be followed and supported by specialized researchers. This proposal shows a multiple range of possible uses that can benefit and help many different research groups of both vanguard and citizen science (Silvertown, 2009).

5. Conclusions

- DIY light traps are a useful alternative for expensive commercially available CDC light traps, although more research work should be carried to develop a standardized construction procedure and to determine the variables that affect the most the resulted capture rates. We also consider that those DIY light traps are a great tool for citizen science and educational projects.
- DIY light traps have been seen to have a general increase of 37 % in captured phlebotomine sand flies compared to CDC commercial traps, although no statistical differences have been seen. This could be due to the employment of a LED-light source or/and to the design of traps.
- More research should be performed with different trap accessories. As seen in trap t3, a higher power supply could damage specimens, so we recommend that until more research is performed a 3.6 W power supply is employed (12 V; 0.3A).

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.prevetmed.2022.105589>.

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