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Tele-entomology and tele-parasitology: A citizen science-based approach for surveillance and control of Chagas disease in Venezuela

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ABSTRACT

Chagas Disease (CD), a chronic infection caused by the *Trypanosoma cruzi* parasite, is a Neglected Tropical Disease endemic to Latin America. With a re-emergence in Venezuela during the past two decades, the spread of CD has proved susceptible to, and inhibitable by a digital, real-time surveillance system effectuated by Citizen Scientists in communities throughout the country. The #TraeTuChipo (#BringYourKissingBug) campaign implemented in January 2020, has served as such a strategy counting on community engagement to define the current ecological distribution of CD vectors despite the absence of a functional national surveillance program. This pilot campaign collected data through online surveys, social media platforms, and/or telephone text messages. A total of 79 triatomine bugs were reported from eighteen Venezuelan states; 67 bugs were identified as *Panstrongylus geniculatus,* 1 as *Rhodnius pictipes,* 1 as *Triatoma dimidiata,* and 10 as *Triatoma maculata.* We analyzed 8 triatomine feces samples spotted from 4 *Panstrongylus*

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geniculatus which were confirmed positive by qPCR for *T. cruzi***.** Further molecular characterization of discrete typing units (DTUs), revealed that all samples contained TcI, the most highly diverse and broadly distributed strain of *T. cruzi*. Moreover, analysis of the mitochondrial 12S gene revealed *Myotis keaysi*, *Homo sapiens,* and *Gallus gallus* as the main triatomine feeding sources. This study highlights a novel Citizen Science approach which may help improve the surveillance systems for CD in endemic countries.

1. Introduction

Neglected tropical diseases (NTDs) are a prominent cause of morbi-mortality in middle to lower-income countries throughout the world (Aagaard-Hansen and Chaignat, 2010). The relationship between poverty and NTDs becomes further apparent in contexts of social unrest (Du et al., 2018), when the need for reliable strategies to stop transmission of these pathologies, especially vector-borne diseases, becomes particularly pressing. In past decades, Citizen Science initiatives have gained traction worldwide, reducing the pace of vector transmission in Africa, Asia, and the Americas (Ashepet et al., 2021). Citizen Science is an approach that integrates the scientific input of non-specialized individuals in research projects, through the collection and distribution of data (Ashepet et al., 2021). In this schema, Citizen Scientists (CS) within designated geographies, provide eco-epidemiological data into larger analytical platforms—thereby actively contributing to the public health of their locale and that of the greater, national level (Gardiner and Roy, 2021). Digital Citizen Science systems can be organized through social networks such as WhatsApp, Facebook, Instagram, and/or text messaging. Such methods of tracking and reporting have now become diffuse internationally, proving particularly helpful in communities severely affected by NTDs (Ashepet et al., 2021). For example, Curtis-Robles's *et al* pioneer work in the southern United States has shown that Citizen Science approaches can be key not only for the generation of requisite quantities of data relating vector phenology and infection prevalence, but also to educating the public on the observable nature of the disease (Curtis-Robles et al., 2015). In 2011, Abad-Franch *et al* hypothesized on the efficiency of community-based vector tracking methods, over traditional active-search approaches—their review proving the former to be more successful historically, in arresting the household re-infestation cycle of NTD vector species (Abad-Franch et al., 2011).

Nevertheless, to date, the disease-mitigating promise of such an approach has not been realized in countries where Chagas Disease (CD) is endemic. The re-emergence of NTDs in Venezuela, following years of the economic and political strife has been well-described (Grillet et al., 2019; Paniz-Mondolfi et al., 2019). Among the most significant of these NTDs is Chagas Disease (CD), a parasitic infection caused by the protozoan *Trypanosoma cruzi*. In Venezuela, the most common transmission route for *T. cruzi* is through feces of the hematophagous triatomine bugs (kissing bugs), of the Reduviidae family (Pérez-Molina and Molina, 2018). Clinical symptoms of CD often manifest years or decades after the infection has occurred and include irreversible damage to the contractile and conducting cells of the heart. This can result in cardiomegaly, heart failure, stroke, and arrhythmias. *T. cruzi* infection may also affect gastrointestinal viscera, effecting motility disorders (dysphagia and bowel obstruction) and organ enlargement (megacolon and mega-esophagous) (Pérez-Molina and Molina, 2018). Although potentially curable in its acute phase, treatment options in the chronic stage are limited to palliative care (Rassi et al., 2010).

Traditionally, vector control strategies against CD in Venezuela have included indoor residual spraying campaigns with organophosphates and the subsidized construction of higher-quality households in rural settings with endemic transmission rates (Feliciangeli et al., 2003a; Aché and Matos, 2001). These campaigns were successful in tempering transmission and reducing seroprevalence (Grillet et al., 2019), but failed to fully arrest transmission of CD in Venezuela. This failure was due in part to the lack of continuous surveillance national programs. It may as well be attributed to the widespread presence of *Rhodnius prolixus* in Venezuela, whose overlapping sylvatic and domestic transmission cycles make household re-introduction of the vector common (Sanchez-Martin et al., 2006). In addition to *R. prolixus,* at least 20 other triatomine species can be found in Venezuela (Cazorla-Perfetti, 2016). Among these, *Triatoma maculata* and *Panstrongylus geniculatus* are responsible for sustaining peri-domiciliary and sylvatic transmission cycles, respectively, and are also associated with oral transmission outbreaks (Cazorla-Perfetti, 2016; Reyes-Lugo and Rodriguez-Acosta, 2000; Alarcón de Noya et al., 2016; de Noya et al., 2017). Differentiating these bugs from other Hemiptera requires specialized training, often limiting the usefulness of reports provided by the general public and even general health care practitioners. Distinguishing triatomines from other look-alike arthropods can be challenging, particularly for the lay public participating in citizen science initiatives. In order to overcome these limitations, several interesting approaches have been developed. For example, Gurgel-Gonçalves *et al* developed an automated digital system to identify triatomine vectors in Brazil and Mexico. This system capitalizes on digital photographs to record color and anatomical signatures of different vectors allowing identification with over 80% accuracy (Gurgel-Gonçalves et al., 2017). In addition, the use of deep learning algorithms has also procured major advantages for effectively portraying accurate levels of identification and increasing the taxonomic coverage of triatomine vectors (Khalighifar et al., 2019). Most importantly, these digital-based approaches have materialized into effective tools for the public. Such is the case of *TriatoKey*, a web and mobile tool developed by Brazilian scientists to assist in the correct taxonomic identification of triatomine species (de Oliveira et al., 2017).

From 2003 to 2018, independent serosurveys from 17 Venezuelan states have reported prevalence rates for *T. cruzi* infection of 10.7% in rural areas (3.323 samples analyzed). *T. cruzi* infection was detected in individuals from all age groups, suggesting active transmission to children younger than 10 years old (15.4% of the studied population) (Añez et al., 2020). Interestingly, positive samples were obtained from patients who lived in distant geographical and ecological conditions, including arid thorn forest from

Falcon and Lara states, arid tropical forest from Anzoátegui, Guárico, Falcón and Lara, and tropical rainforest and piedmont from Barinas, Cojedes, Portuguesa and Zulia states (Añez et al., 2020).

The re-emergence of CD and other NTDs in Venezuela has been ignored for the most part by national authorities and has received little attention from international stakeholders (Gabaldón-Figueira et al., 2021). In the absence of a functional epidemiological surveillance program, researchers have needed to develop novel strategies to understand the transmission of CD in Venezuela. In that regard, tele-entomology offers an attractive alternative approach, providing support to patients and healthcare providers for the morphologic identification of putative vectors of CD, while concurrently allowing researchers to collect geographical data to track the distribution of these insects, and the parasites they transmit, based on community reports (Gardiner and Roy, 2021). Despite limited access to internet services, approximately 60.4% of the Venezuelan population owns a smartphone, and social network-based telemedicine campaigns have been successful in the past for monitoring the emergence and evolution of outbreaks of Zika, and more recently, COVID-19 (Faria et al., 2016; COVID-19 Map - Johns Hopkins Coronavirus Resource Center, 2021; De Oliveira et al., 2020).

Herein, we present the results on the feasibility of the proof-of-concept #TraeTuChipo (Bring your kissing bug) campaign. #TraeTuChipo is a community-based Citizen Science initiative which relies on a digital, user-friendly platform for remote entomologic diagnosis of CD. The project requires of its participants, little more than smartphone cameras and access to a social network—being inasmuch, suitable for CD surveillance within remote low-resource community settings. This pilot observational study began in January 2020 and remains ongoing. Our primary aim had been the generation of a database describing the geographical distribution of triatomine bugs. Secondary objectives included assessment of the prevalence of infection with *T. cruzi* among the collected insects, including a description of the parasite DTUs, and identification of the main feeding sources for triatomine bugs collected in rural and urban Venezuela. Finally, we provided Citizen Scientists the requisite training in correct identification and collection of triatomine bugs. Our results suggest on the excellent potential and retractability of this program for monitoring the distribution of CD vectors in other CD endemic countries.

2. Materials and methods

2.1. Citizen Science-based strategy workflow

The campaign was intended as an alternative surveillance strategy to monitor triatomine sightings and is based on a simple workflow: a) A Citizen Scientist reports the presence of a specimen through online surveys, social media, or a telephone number enabled exclusively for this purpose. b) After careful review of the report, the Citizen Scientist is contacted by a researcher with training in medical entomology and instructed to provide pictures of the captured specimen. c) Accurate entomologic diagnosis is provided to the Citizen Scientist within the next 24 h. d) If the specimen is brought into one of the previously established collection facilities, parasitological diagnosis, entomological identification, molecular detection of the parasite including genotyping and feeding sources identification of the triatomine feces can be performed.

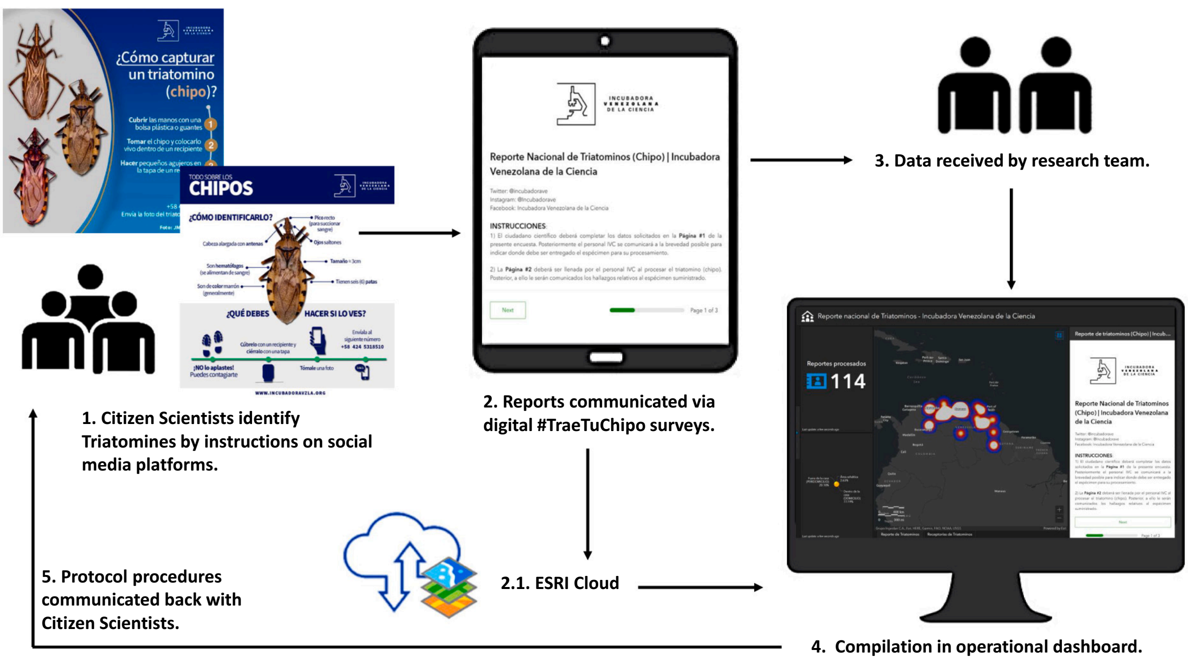

Fig. 1. Real-Time Reports workflow between researchers and Citizen Scientists (CS).

Additionally, Citizen Scientists can report sightings through social networks, including Twitter, Instagram, Facebook, and WhatsApp, by using the hashtag #TraeTuChipo. Reports can be made by any citizen, just by submitting photos of the specimen and basic eco-epidemiologic information for their identification. The submitter can then visit a previously established collection center (including schools, rural medical centers, churches, communal houses) to deliver the captured insect/s. Collection centers receive the specimens and keep them safe for later processing. Surveys can be filled through a dedicated secure, free application or a website, which directly feeds data to an operational dashboard developed by researchers.

2.2. *Real-time case recording*

We used a real-time reporting platform assisted by interactive visual interfaces (MacIejewski et al., 2011) to construct a graphic dashboard for all previously filed reports of triatomine sighting and/or bug bites. The platform can process data as quickly as it is received, providing the Citizen Scientists, and researchers with precise and instantaneous information about triatomine geographic distribution and hot spots within their community or neighboring locations.

Case reporting is made through an operational dashboard (Reporte de triatominos (Chipo)|Incubadora Venezolana de la Ciencia, n.d.) powered by ESRI-GIS mapping software (GIS Mapping Software et al., n.d.). ESRI's digital ecosystem allows interconnection with other useful tools such as "Survey123" (ArcGIS Survey123, n.d.), user-friendly software for survey design. With each kissing bug report made, the Citizen Scientist completes a survey indicating eco-epidemiological information (such as general features of the collection area, the specific site of collection, history of known cases of Chagas disease diagnosed in the area, and possible triatomine bites), and submits photographs. The resulting dashboard can be shown on different media, allowing the creation of a situation room (National Triatomine Monitor) where community leaders can access the metrics obtained based on CS reports, and obtain feedback and recommendations from the research team **(**Fig. 1**).**

The National Triatomine Monitor (Reporte nacional de Triatominos - Incubadora Venezolana de la Ciencia, n.d.) can be accessed by public and healthcare providers for the collection of real-time data on (i) frequency of national reports with precise geographic

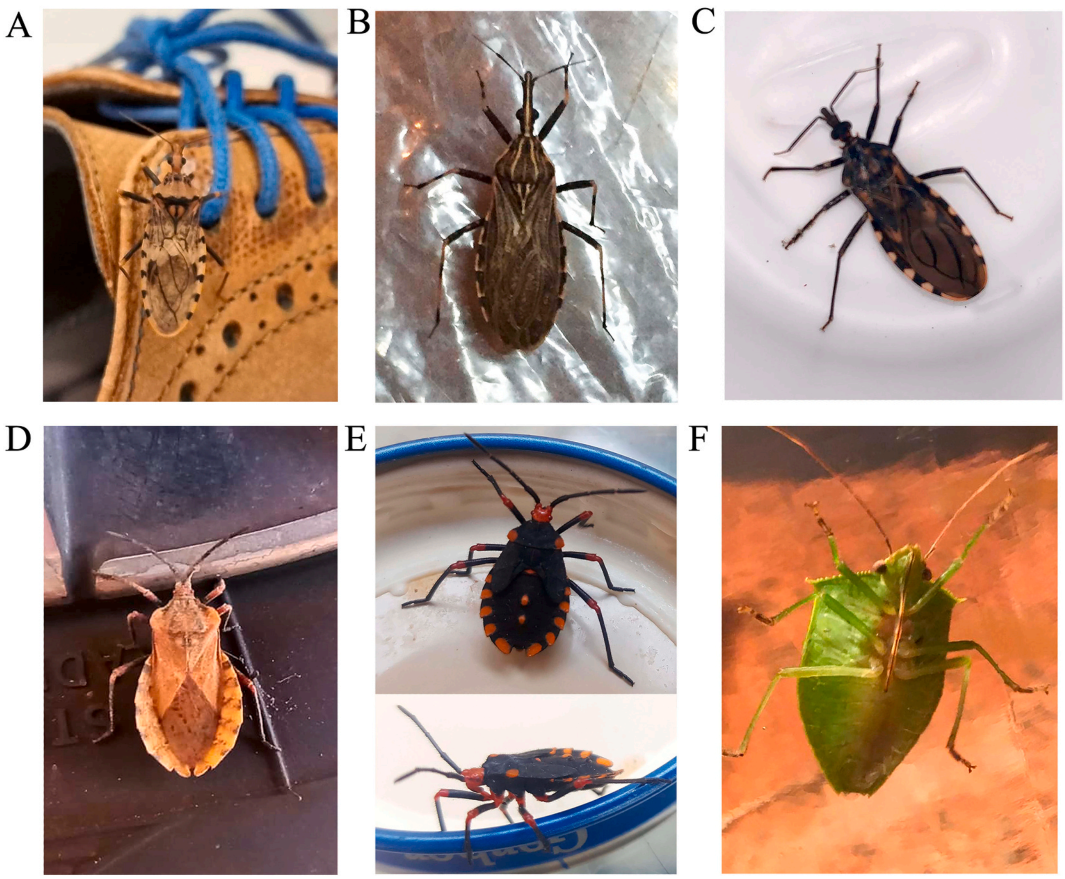

Fig. 2. Triatomines and Non-triatomines collected by Citizen Scientists (CS) between 2020 and 2021. (A) *Panstrongylus geniculatus*, reported from Caurimare, Distrito Capital, Venezuela. (B) *Rhodnius pictipes* reported from Santa Elena de Uairén, Bolivar state, Venezuela. (C) *Triatoma maculata*, reported from Buena vista, Lara State, Venezuela. (D) Non-triatomine identified as Spartocera *spp.* (E) Non-Triatomine identified as *Coreidae spp* (F) Non-triatomine identified as *Nezara viridula* (Chinche verde).

coordinates, (ii) access to a gallery of high-resolution photographs of hematophagous and non-hematophagous Reduviidae insects, and (iii) learning resources to guide the identification of CD vectors (Reporte nacional de Triatominos - Incubadora Venezolana de la Ciencia, n.d.).

2.3. Collection, identification, and dissection of triatomine bugs

Triatomine bugs (Kissing bugs) have been collected by healthcare providers and Citizen Scientists from rural and urban communities from several states around Venezuela (Lara, Portuguesa, Capital District, Miranda, Falcón, Trujillo, Aragua, and Bolivar) since 2020. As soon as a preliminary identification of a triatomine bug is made (based on the provided photographs), Citizen Scientists are instructed to collect the specimen following basic biosafety measures. Insects are then collected by local volunteers with support from medical entomologists, and if confirmed to be a triatomine bug, the specimen is processed in one of the partner labs distributed across the country, with remote support from a medical entomologist (Fig. 2).

Following taxonomic classification (Whatman FTA card technology, n.d.), all specimens were dissected according to the following protocol. The antenna and legs were removed and collected for further molecular studies. Afterward, a cross-section is performed at the third or fourth abdominal segment, to sample the entire GI tract, particularly the posterior midgut where the metacyclic trypomastigotes are generally located. Samples were homogenized with 0,9% saline and viewed under a conventional optic microscope at 10, 20, and 60× for the identification of epimastigotes and trypomastigotes. Parasitological positive samples were categorized based on parasite load as follows: (+) 10 or less protozoan per microscopic field, (++) 11–20 protozoan per microscopic field, (+++) >20. The remaining intestinal content was used to impregnate the Whatman® FTA® card (FastPrep-24™ 5G Instrument|MP Biomedicals, n.d.) and used for molecular diagnosis and genotyping.

A full report with basic recommendations was presented to individuals who reported the bug, and if possible, a field visit was carried out by local volunteers for a clinical and epidemiological assessment as well. Finally, following the outcome of the visit specific findings and recommendations are provided to the Citizen Scientist.

2.4. DNA extraction, molecular detection, and genotyping of *T. cruzi*

Samples on FTA cards were cut and placed into lysis tubes, tubes were disrupted using FastPrep-24™ 5G bead beating grinder and lysis system (Hernández et al., 2016), subsequently, 300 μl of each sample were employed. Using the DNeasy Blood and Tissue Kit (Qiagen, Hilden, Germany) the samples were submitted to DNA extraction, and then DNA concentrations were determined using a NanoDrop ND-100 spectrophotometer (Termo Fisher Scientific Inc., Waltham, MA, USA).

Molecular detection of *T. cruzi* was performed using the Cruzi1 (5′-AST CGG CTG ATC GTT TTC GA-3′) and Cruzi2 (5′-AAT TCC TCC AAG CAG CGG ATA-3′) primers, and the Cruzi3 FAM-CACACACTGGACACCAA-NFQ-MGB DNA probe amplifying the satellite DNA of the parasite. The qPCR test was considered positive when the amplification exceeded the threshold of fluorescence 0.01 as reported elsewhere (Souto et al., 1996).

Genotyping was performed by PCR using the intergenic region of the mini-exon gene to detect TcI or TcII-TcVI with the amplification of a fragment of 350 bp or 300 bp respectively. Using the TCC (5′ CCCCCCTCCCAGGCCACACTG 3′), TC1M (5′ GTGTCCGCCACCTCCTTCGGGCC 3′) and TC2 (5′ CCTGCAGGCACACGTGTGTGTG 3′) primers (Souto et al., 1996). The thermal profile consists of an initial denaturation at 95 °C for 5 min, followed by 5 cycles of 94 °C for 1 min, annealing at 67 °C and 1 min at 72 °C, then 5 cycles 94 °C for 1 min, annealing at 65 °C and 1 min at 72 °C; 94 °C for 1 min, annealing at 63 °C and 1 min at 72 °C, and 30 cycles at 94 °C for 1 min, annealing at 61 °C for 1 min and 1 min at 72 °C, followed with a final extension at 72 °C during 10 min. The PCR products were analyzed by a 1,5% agarose gel electrophoresis, stained with SYBR safe (Dumonteil et al., 2018).

2.5. Feeding sources identification

The PCR products of the mitochondrial 12S gene were obtained through the amplification of the 215-bp fragment using the following primer set L1085 (5′-CCCAAACTGGGATTAGATACCC-3′) and H1259 (5′-GTTTGCTGAAGATGGCGGTA-3′) (Lent and Wygodzinsky, 1979). These fragments were purified and prepared with ExoSAP-IT™ Express PCR Product Cleanup Reagent (Applied Biosystems) for sequencing, which was performed by Macrogen, Inc. (Seoul, South Korea) using the Sanger sequencing method. The resulting sequences were edited in SeqMan and then submitted to BLAST (Basic Local Alignment Search Tool) (BLAST, n.d.) for a similarity search, filtering those sequences with <98% of identity. The most frequent high-quality sequences were selected to describe the feeding preferences of triatomines.

3. Results

3.1. Triatomine bug identification and geographical distribution

A total of 79 triatomine bugs corresponding to 67 *Panstrogylus geniculatus, 1 Rhodnius pictipes, 1 Triatoma dimidiata and 10 Triatoma maculata* were collected by Citizen Scientists in this study. Eleven of these triatomines were collected alive. Thus far, insects have been collected in Lara, Portuguesa, Bolivar, Miranda, Trujillo, Aragua, Sucre, Zulia, Táchira, Falcon, Yaracuy, Carabobo, Anzoategui, Nueva Esparta, Guarico, Vargas, Delta Amacuro, the city of Caracas (capital district) and one report from the east bank of the Cuyuni River in the Esequibo territory. (Table 1; Fig. 3A).

3.2. *Trypanosoma cruzi* DTU characterization

The Triatomine bug intestinal content collected on the FTA cards was positive by end-point qPCR for *T. cruzi* for 4 bugs. All samples belonged to the TcI DTU. All triatomine bugs were previously taxonomically identified as *Panstrongylus geniculatus* and were collected by Citizen Scientists inside the houses. **(**Fig. 3B**).**

3.3. Triatomine bugs feeding sources identification

Feeding sources were determined in 8 feces samples collected on FTA cards from 4 triatomine bugs (*Panstrongylus geniculatus*), identifying 3 species: *Myotis keaysi* (bat, $n = 2$), *Homo sapiens* ($n = 6$), and *Gallus gallus* (red junglefowl, $n = 1$) as the main feeding sources. All triatomines that fed from human blood were positive for infection with *T. cruzi*. **(**Fig. 3B**).**

4. Discussion

CD, a chronic condition with cumulative burden, remains a public health threat in the Americas. As evidenced by the 21 countries in which the disease remains endemic despite global efforts of vector control (Chagas disease (also known as American trypanosomiasis), n.d.), new initiatives are in high demand for the improvement of CD surveillance in line with the Sustainable Development Goals proposed for 2030 (*Ending the Neglect to Attain the Sustainable Development Goals: A Road Map for Neglected Tropical Diseases* 2021–2030, n.d.). A virtual approach to Citizen Science seems a promising strategy, as social media campaigns allow for rapid, organized diffusion of public health messages and are useful to raising awareness for sanitary concerns, beneficial lifestyle changes, disease risk factors, and common symptoms among a select population. While traditional means of communication like radio, television, and newspapers continue to be helpful, the gold-standard of public accessibility by scientific spheres has emerged to be the scope of modern information outlets *i.e.*, texting, email, websites, and social media platforms, even in low-income countries (Abroms and Maibach, 2008). The effectiveness of any public health campaign is based on two important factors: (i) optimal message design and delivery, and (ii) sufficient reach and frequency (Noar, 2006; Hornik, 2002). However, few initiatives have used this approach in tracking and reporting CD.

Tele-parasitology is the modern offspring of the general citizen science approach—one of rather high-yield data output given the natural efficiency and accessibility of the internet. Further, it offers a quiescent but persistent educational resource for the training of healthcare providers and the general public. This is to say that, by means of this platform, the skills pertinent to handling and identification of disease carrying insects becomes so accessible and routine, that the community learns by a habit which proves protective of the entire public sphere. In support of this, our results confirm that data from an effective teleparasitology program illustrates the geographic distribution of triatomine bugs (Fig. 3A and Table 1); it also identifies communities in which vector control campaigns should be prioritized.

Some interesting details of our findings also show that *Panstrongylus geniculatus*, a species traditionally associated with peridomestic and sylvatic transmission cycles, was the most commonly reported triatomine in domestic areas, matching the results reported by Carrasco *et al* and Nakad *et al* in Metropolitan District of Caracas (Carrasco et al., 2005; Nakad Bechara et al., 2018). Together with a curious absence of *Rhodnius prolixus* (traditionally considered to be the most common vector of CD in Venezuela (Feliciangeli et al., 2003b)), these findings hint atpossible changes in the ecological distribution of vectors and offer new food for thought to the ongoing vector-control programs in Venezuela. Still, a longer sampling period is fundamental to concretely establishing whether *P. geniculatus* has become a major CD-transmitting species in the country.

Similar tele-strategies tailored to the improvement of public health have been employed in other regions of the world. In 2015, Dr. Curtis Robles' team surveyed municipalities across the state of Texas with a similar strategy as that which we have been employing. The study received 1980 reports—a sample size comprising seven distinct species (Curtis-Robles et al., 2015). Furthermore, Abad-Franch et al. published a review in 2011 whose findings thoroughly supported tele-parasitology and the passive inputs of residential communities into data systems, to be of greater longitudinal significance to arresting the cycle of triatomine re-infestation (Abad-Franch et al., 2011). We gather then, that our approach has promise to grow to such larger proportions with time as well. An increase in the prevalence of CD infection is subject to a combination of critical variables such as (i) ecological factors related to triatomine habitats and (ii) epidemiological factors inherent to the current living conditions of affected households or communities. NTDs are strongly

Table 1
Percentage of Triatomine species and Non-triatomines reports received through the platform in Venezuela between 2020 and 2021.

	Percentage ($n = 113$)	Positive (%)	Negative (%)
Triatomine species ($n = 79$)			
Panstrongylus geniculatus	59,29% ($n = 67$)	19.04% ($n = 8$)	7,14% ($n = 3$)
Triatoma maculata[*]	8,84% ($n = 10$)	0%	0%
Rhodnius pictipes[*]	0,88% (n = 1)	0%	0%
Rhodnius prolixus	1,76% (n = 2)	0%	0%
Triatoma dimiata[*]	0,88% (n = 1)	0%	0%
Non-triatomines ($n = 31$)	28,31%	NA	NA

NA = Non applicable.
[*] Specimens were only identified taxonomically without parasitological analysis.

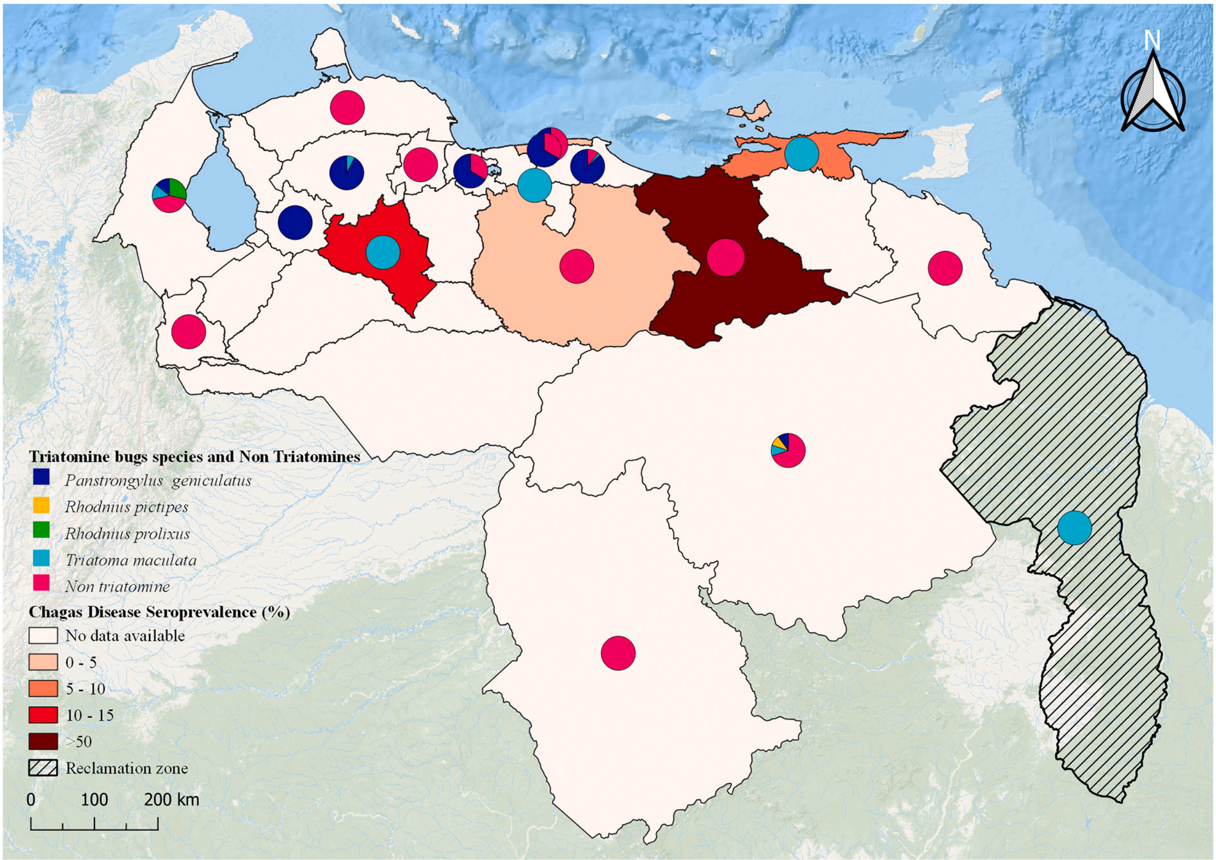

Fig. 3. A) Geographical distribution of the Triatomines and non-triatomine bugs collected by Citizen Scientist in Venezuela between 2020 and 2021. In a spectrum of a light red (0–5%) to dark red (>50%) available seroprevalence of Chagas Disease (CD) is depicted. B) Geographical distribution of the triatomines bugs positive by qPCR for *T. cruzi*. The map was generated using QGIS software. (https://www.qgis.org/es/site/). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

related to poverty and conflict (Du et al., 2018). Our results are encouraging, suggesting that a scale-up and a national rollout of this and similar campaigns (*e.g.*, with mosquito-borne and tick-borne infectious) could provide independent data sources on the distribution of CD and other vector-borne diseases in the country, and the definition of higher risk areas, where actions coordinated with national authorities and foreign organizations involved in the control of NTDs in the country could take place.

In our experience with the Middle-Western region of Venezuela, the efficiency of vector control initiatives for CD has been enhanced by improved community monitoring. A key factor was the establishment of direct and continuous lines of communication between research institutions and community members by the training of Citizen Scientists to record the eco-epidemiological data. This standardized reporting method has been established as a popular community-based activity within a severely-affected regions highlighting the feasibility of this strategy. Furthermore, the study remains in yet -initial stages of the success which such a citizen-oriented strategy promises. It is important to highlight the core of the project as being public participation. With the onset of the public health crisis, it has been difficult to effect mass distribution, public participation, and information retention of counsels outside the scientific domain of COVID-19-pertinence. Nevertheless, with an already-broad geographical reach, our tele-strategy shows potential to gain traction in Venezuela, as well as in greater Latin America, as the country emerges out of a taxing pandemic.

There are some limitations to the study which are chiefly a function of the accessibility of social media platforms. We may have been receiving most significant data sets from Venezuelan states with larger urban areas with skewed data from rural populations were the content is most relevant for this study. Thus far, our data input has been limited by these factors and in turn offers bias from the regions in which the marketing of our campaign has not yet been successful. We see thus, a bias from both the information provided, and that absent from a complete understanding that is inherent of a large and well-distributed sample size. Also, population bias of the social media data (Twitter, Instagram and Facebook) may have also contributed to data source bias based on language limitations, term definitions, hashtags usage and web search behaviors. Furthermore, the nature of tele-parasitology is more favoring of participation by younger rather than older community members making education of the next generations imperative in the management of the sanitary welfare of their own communities. In a way, this limitation encourages a “building-from-the-ground-up” approach to the scientific education of the country's youth with potential to rebuild a scientifically-crumbling nation. In addition, this study faced the challenges of the COVID-19 pandemic limiting the access to communities and impacting first hand data collection.

In summary, herein we demonstrate the feasibility of a monitoring strategy utilizing tele-parasitology and a Citizen Science-based approach for the entomological surveillance of CD in Venezuela. The success of this strategy in Venezuela supports its potential use to strengthen surveillance systems for CD in other endemic countries.

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Declaration of Competing Interest

The authors have no conflicts to declare.

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