Evaluation of an *Aedes*-control intervention scaled-up under a multisectoral approach in a dengue hyperendemic municipality in Colombia

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Abstract

Background

Aedes aegypti transmitted diseases have gained significant attention in Colombia, especially with the introduction of Chikungunya and Zika in the Americas during 2014 and 2015, and the increasing spread of the dengue virus (DENV). Even though important progress has been made in the reduction of these illnesses, evidence-based scaled-up programmes for effective control are limited in many settings, restricting the possibility of using evidence to inform the utilisation and expansion of new tools, technologies, and approaches. In one of Colombia's most hyper-endemic DENV cities (Girardot), the scaling-up of a community-based intervention under a multisectoral approach ("Girardot *Aedes-Free*") was carried out between 2015 and 2018, aiming to reduce *Ae. aegypti* density, as well as dengue incidence. This programme included the distribution of insecticide treated water covers. The aim of this thesis was to investigate the effectiveness of the "Girardot *Aedes-Free"* intervention, and to assess the critical elements for implementing the intervention at scale and developing an effective multisectoral approach to scale-up the intervention.

Methods

To assess the effectiveness of the scaled-up intervention on dengue incidence, the number of dengue cases and associated factors were analysed from available data sets from the local Colombian disease surveillance system. Different statistical analyses were used (Propensity score matching, Arma, and Differences in Differences (Diff in Diff)). In addition, different *Ae. aegypti* indices were calculated from baseline and follow-up household and public premises entomological data sets of study logs. The impact of the intervention in reducing *Ae. aegypti* indices in household and public premises was analysed using Diff in Diff, difference of endpoints and logistic regression models for both households and public premises.

A process evaluation using a mixed-method approach was conducted to analyse the process of scaling up and implementing the intervention, as well as the importance of multi/intersectoral collaboration approach in scaling-up the intervention. Secondary data from semi-structured interviews with key actors, study logs, policy documents, and other official documents such as guidelines, minutes, statutes, and decrees were analysed to offer insight into the intervention implementation and context.

Results

The "Girardot *Aedes-Free"* intervention can be defined as a complex community-based intervention that comprises four components that interacted at different levels (household covering productive *Ae. aegypti* breeding sites with insecticide-treated covers (ITCo), school, community, and institutional actions). The

intervention reached 6127 households and 5709 insecticide-treated water-holding container covers were installed. Thirteen months after the intervention was implemented, entomological indices decreased overall in both intervention and control areas but decreased further in intervention areas, with significant differences, except for container indices (CI) and pupa per person indices (PPI) which increased in control areas. The CI decreased in intervention areas after the intervention (from 12% to 6%) and this decrease was significant (diff – 0.06, 95% CI [- 0.08, -0.04]) but increased slightly in control areas after intervention (from 13% to 15%), although the differences were not significant (diff 0.02 95% CI [-0.02, 0.06]). The Breteau Index (BI) decreased from 22.6 to 11.7 in intervention areas (diff 0.11, 95% CI [0.08, 0.14]) and from 31.6 to 27 in control areas (diff 0.05, 95% CI [0.00, 0.10]). Entomological indices in public spaces were higher than indices in households and decreased overall in both intervention and control areas after the intervention was implemented. The results of logistic regression models for both households and public spaces showed that after the intervention, there was a lower likelihood of finding immature forms of *Ae. aegypti* in intervention areas compared to control areas.

Regarding impact on the reduction of dengue cases, although there is some evidence in favour of the intervention, there is no conclusive evidence.

The scaling-up of "Girardot *Aedes-Free"* complied partially with a "vertical approach" (conducted and taken up by the governmental sector) and a "horizontal approach" (replication of a successful intervention). Two main factors hindered the expansion of the intervention and its integration into vector control polices and hence the sustainability of the intervention. These included 1. territorial governance, such as management and leadership, technical capacity, participation and institutional structure of a territory, and complexity of installation of household level intervention components and 2. political will of the local authority (Mayor). Furthermore, it was evidenced that the multisectoral collaboration was established under a genuine collaboration and has the potential to be successful in time. However, the are some challenges, including lack of human and financial resource mobilization and allocation, lack of monitoring system of actions, that need to be addressed to maintain its impetus.

Conclusion

The outcome evaluation indicates that the intervention can reduce dengue vector populations but there is no conclusive evidence that the intervention can reduce dengue incidence. Greater coverage of the intervention, improved vector and dengue surveillance systems and sustainability of the multisectoral approach (led by the Mayor of the municipality) are required for further impact.

The understanding of the process of implementation of scaling-up a vector control intervention provided useful information on how to scale-up and how to build and implement a multisectoral approach for the control and prevention of dengue and what factors must be addressed.

The information from this study will support recommendations to improve DENV and *Ae. aegypti* prevention and control in Colombia and other developing countries. Furthermore, the evaluation of the multisectoral approach as part of a vector control intervention will help strengthen other multisectoral collaborations that have been implemented in Colombia following national guidelines and yet are not sustainable or functioning.

Table of contents

List of Tables

List of Figures

List of Acronyms

P

R

S

T

U

V

W

Chapter 1 Introduction

This dissertation explores a broad range of diverse aspects (mechanisms of impact, contextual factors, processes, fidelity and outcomes) involved in the implementation of the scaling-up of a complex intervention for the control of *Aedes aegypti,* and elements that are crucial for building an evidence base that informs policy and practice in *Aedes* control in Colombia.

The overall aim of this thesis was to investigate the effectiveness of a scaled-up *Ae. aegypti* control intervention on the incidence of dengue and *Ae. aegypti* populations, and to assess the process of implementing the scaling-up of an intervention under a multisectoral and intersectoral approach in a hyperendemic dengue municipality of Colombia during 2015 and 2018.

1.1 Rationale of the study

Aedes-borne diseases account for around 23% of the estimated global burden of Vector-Borne Diseases (VBD) (1). They pose a significant economic cost (US $ 2.1 billions per year), not only for governments in endemic countries, concerning the cost of case management and vector control activities, but for households regarding expenditures for treatment and protective measures (2–10). *Ae. aegypti*, the main vector of dengue virus (DENV), is now globally widely distributed, thus increasing disease burden due to different aspects of its biology, ecology (climate conditions, temperature, landscape modifications), and other anthropogenic factors.

Dengue is widely associated with complex relationships between different ecological, biological, and social factors of urban and peri-urban environments, all of which are particularly challenging for vector control efforts. Ecological factors refer to climate (rainfall, humidity, temperature, etc) and the natural and man-made ecological setting (unplanned urbanization) (11,12). Biological factors relate to the behaviour of the vector, *Ae. aegypti,* and transmission dynamics of dengue (different serotypes) (13). Social factors incorporate a series of influences relating to health systems including; the weakening of surveillance systems,vector control programmes (14) and health services (15) and their political contexts (e.g. health sector reforms, decentralization (16)); public and private services such as sanitation and sewage, garbage collection and water supply; "macro-social" events such as demographic growth and urbanization, and community and household-based practices; knowledge and attitudes, and how these are shaped by large-scale forces such as poverty (17,18), social inequality (19) and community dynamics including human movements (20,21).

Due to the resurgence and continuously increasing dengue threat, an international effort for strengthening dengue control was promoted by the World Health Organization (WHO) under the leadership of Special Programme for Research and Training in Tropical Diseases (TDR). Since 2006, it was recognized that new vector control interventions are needed, to control vector populations sustainably (36). These new interventions should take into consideration local vector ecology, disease epidemiology and resources. In response, a collaborative effort between TDR and the Ecosystems and Human Health Program of the International Development Research Centre (IDRC) launched the Eco-bio-social (EBS) /Ecohealth research programme, which aims to improve dengue disease prevention through multi-level/multi-scale and trans-disciplinary analysis, ecosystem-related, biological and social ('eco-bio-social') determinants, and to develop and evaluate community-based public health interventions (targeting *Aedes* mosquito habitats and delivered through intersectoral actions (Figure 1.1).

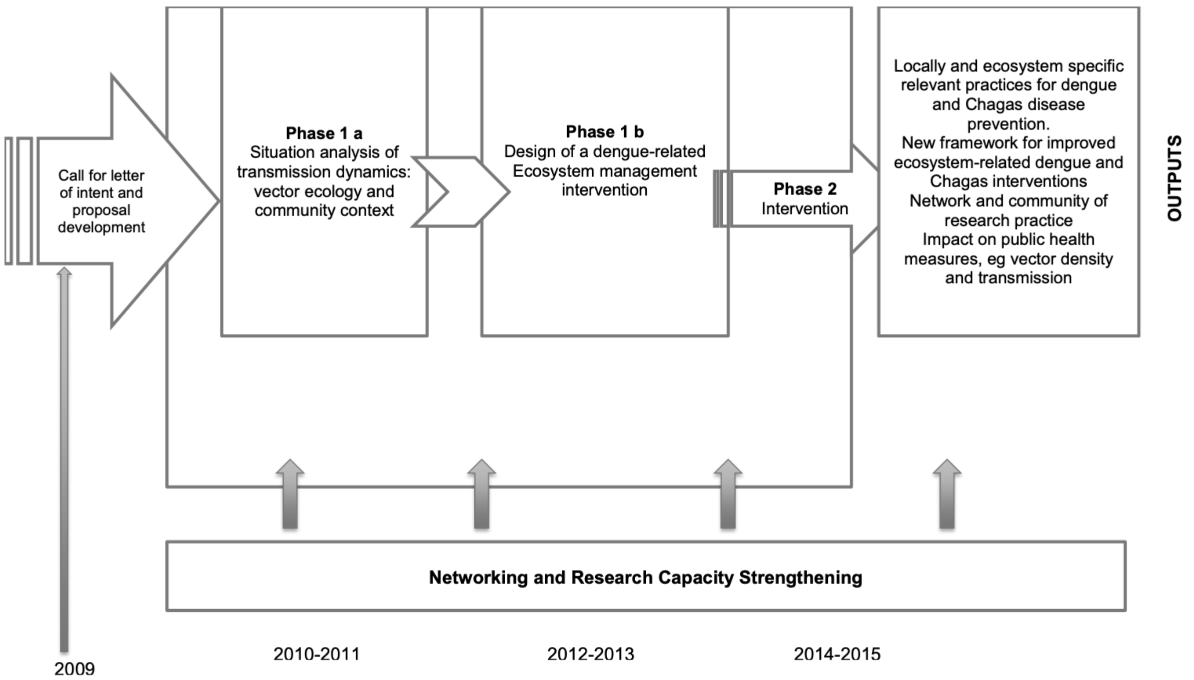

Figure 1.1. Conceptual framework of the research phases and objectives of the TDR/EBS initiative.

This effort comprised three multi-country studies.

1. An initial pilot study in Colombia (37) and Brazil (38): Eco-Bio-Social aspects of dengue. This study was completed in 2005.
2. A six-country study in Asia and Southeast Asia: Eco-Bio-Social Research on dengue in Asia (27).

3. A three-phase multi-country study in nine sites in Latin America (México, Ecuador, Colombia, Brazil and Uruguay): Community-based Ecosystem Management Interventions for improved dengue and also Chagas disease prevention (39–41).

The third multi-country study is the most recent phase, launched in 2009. Initially, a comprehensive approach was built based on several study sites (22–24) that investigated the complexity of eco-bio-social determinants of dengue in urban areas. These studies highlight that vector control requires setting-specific approaches that combine environmental management practices with community mobilization and engagement, intersectoral and multi-stakeholder partnerships, principles of Integrated Vector Management (IVM) (25), and other country-specific policies such as an Integrated Management Strategy (IMS) (26).

Later on based on the evidence and following WHO's strategy for IVM (25) and the IMS (26), the initiatives went beyond studying the associated factors by implementing and testing locally and ecologically adapted vector control interventions.

Specifically, in Colombia from 2013 to 2014, a vector control intervention (Girardot *Aedes-Free*) was implemented in one of the most hyperendemic municipalities of Colombia (Girardot). Mainly the intervention consisted in covering windows and doors and the most productive household water-holding containers for *Ae. aegypti* with long-lasting insecticide-treated nets (LLITN) (with deltamethrin 50 mg/m2, Vestergaard-Frandsen, Lausanne, Switzerland).

A cluster randomized controlled trial (cRCT) was conducted to test the efficacy of the intervention in reducing the *Ae. aegypti* density measured through pupae per person Index (PPI) as a proxy for adult density (29) among other immature indices. The study compared ten control and ten intervention areas comprising 100 households each. In control clusters, routine vector control activities (Abate, health education, and occasional public space spraying of an ultra-low volume of Malathion) were conducted. Intervention clusters included, in addition to the routine vector control activities, insecticide-treated curtains (ITC) for windows and doors, and insecticide-treated covers (ITCo) for the most productive water containers. Community participation in the design and implementation of the interventions was essential for the development of the project (30).

A total of 3483 curtains were installed in 958 households and 354 covers were installed in water containers. Differences in differences analysis between intervention and control clusters showed a significant reduction of the PPI in the intervention clusters. The PPI declined 71% (from 0.75 at baseline to 0.22 at the second follow up) in the intervention group, compared to 25% (from 0.40 to 0.30) in the control group. After the intervention with covers, the pupae productivity decreased 60% (from 970 to 388), and in the control group 16% (from 394 to 339). Furthermore, 60.1% of residents reported a willingness to pay for the covers, 83.2% would recommend them to friends and neighbours, 26.4% reported less use of do-it-yourself insecticide sprays and indicated that the median cost of the sprays was US$8 (29).

The cost per household was US$48, where the LLITN were the main driver of the costs (4). The cost of the intervention is high, but when compared to local out-of-pocket expenditures (US$13.27) or indirect costs of dengue in Colombia (US$197.10) (6), the investment seems to worthy.

In the light of the efficacy results, and following the recommendations of the WHO response strategy 2017 (1), the project in Colombia *("Ecobiosocial approach for the design and implementation of a sustainable strategy for dengue vector control in Colombia")* implemented a scaling-up phase, extending the intervention to other geographic areas with the aim to broaden the impact in dengue local transmission. As a key strategy to reach the institutionalisation of the intervention and long-term viability, a multisectoral and intersectoral action approach amongst municipal entities from different sectors (health, social development, tourism, academic and education) was proposed (Chapter 3. Description of the intervention). As part of this scaling-up phase a quasi-experimental study, pre-post test, with a control group was designed.

The scaling-up phase of the Colombia initiative was an opportunity to assess many aspects that still needed to be addressed. There are gaps in understanding the factors that influence the process of expanding and institutionalising the intervention, and the role that plays a multisectoral approach in this process. For example, it was clear from the literature review that there is a lack of evidence around the effectiveness of scaling *Ae.aegypti* interventions in dengue transmission. Scaling-up health interventions is a complex process. Settings beyond controlled scenarios, like those of efficacy trials, pose several challenges (political, financial, administrative and community leaderships) in the implementation process of an intervention at scale. These challenges not only affect the impact of an intervention but its integration into local programmes, and future sustainability.

Most studies of dengue control interventions have focused on analysing their effects in reducing vector densities. Analyses of implementation processes of these interventions against dengue are scarce (31–33). Moreover, there are fewer studies that describe the development and implementation fidelity of interventions against dengue (34), and even less so in Colombia. The analysis of implementation fidelity (35) is important, as it not only ensures that the observed results are linked to the intervention but also, generates ideas for improving the implementation of the intervention.

A greater understanding of the above factors allowed better recommendations on how and under what conditions the intervention was scaled-up and what impacts it produced on dengue transmission.

1.2 Aim, research questions and objectives

1.2.1 Overall Aim

Investigate the effectiveness of a scaled-up *Ae. aegypti* control intervention on the incidence of dengue, and assess the process of scaling up the intervention in a hyperendemic municipality in Colombia during 2015 and 2018.

1.2.2 Research questions

- What is the effectiveness of a community-centred environmental management intervention in reducing dengue cases and *Ae. aegypti* populations in a hyperendemic municipality of Colombia?
- What are the factors (implementation, mediators and contextual) that drive the process of scaling-up an *Aedes*-control intervention, that aims to reduce dengue reported cases in a hyperendemic municipality of Colombia?
- What are the factors that drive the effective development and adoption of a multisectoral and intersectoral collaboration as a practice in scaling-up an *Aedes*-control intervention for reducing dengue reported cases in Colombia?

1.2.3 Objectives

- To evaluate the effectiveness of an *Aedes*-vector control intervention in the reduction of *Ae. aegypti* infestations and dengue incidence in a hyperendemic municipality of Colombia.
- To document and analyse the process of scaling-up an *Aedes*-control intervention by examining its implementation, identifying the contextual factors, and clarifying the causal mechanisms through which the intervention produces its impact.
- To evaluate the factors that drive the development of a multisectoral collaboration for *Ae. aegypti* control in Colombia at a municipal setting

1.3 Overview of thesis objectives and methods

This thesis is based on one empirical case contributing to four studies (Studies 1–4); two quantitative studies (Studies 1 and 2) and two mixed-method studies (Studies 3 and 4) based on the examination of one subject of study (the case). I choose as subject of study the "Girardot *Aedes-Free*" intervention, carried out in a hyperendemic municipality of Colombia for the control of *Aedes*-transmitted diseases as a focus for study. This case study was chosen based on its availability, meaning that access to them and organisations involved was granted through negotiations with existing contacts, either via local actors or from within the organisations, and my previous involvement in the project as principal investigator. As principal investigator and study manager for "*Girardot Aedes-Free*" project I led the preparation of all aspects of the project except the economic evaluation of the intervention.

Table 1.1 presents an overview of how the specific aims of the thesis are linked to the case, the studies, and the main theoretical and methodological approaches.

Table 1.1. Overview of the objectives of the thesis and their relations to research design, data sources and theoretical approaches used.

Study	Objectives	Theoretical framework	Research Design	Data sources
Study 1	To quantify the effectiveness of the intervention in reducing *Ae. aegypti* abundance.	Outcome evaluation	Observational Cross-sectional study	Entomological surveys in public and private premises from intervention and control areas both, before and after implementation of the intervention (study logs)
Study 2	To evaluate the effectiveness of an *Aedes*-vector control intervention in dengue incidence in a hyper-endemic municipality of Colombia.	Outcome evaluation	Ecological study	Dengue surveillance data from Girardot (study site)
Study 3	To assess the process of implementation, clarify causal mechanisms and identify contextual factors	Process evaluation Implementation research	Mixed-methods approach	In-depth interviews, focus group discussions (FGD), and document review.

	associated with the outcomes produced by the scaled-up intervention	Fidelity ExpandNet		
Study 4	To investigate the development and sustainability of a multisectoral approach built as the main strategy for scaling-up "Girardot *Aedes-Free"* intervention.	Multisectoral action Process evaluation	Mixed-methods approach	In depth semi-structured interviews, stakeholder mapping and analysis and document review

1.4 Outline and organization of the thesis

The chapters are organized according to the specific objectives of the thesis.

Chapter 1 is an introduction to the structure of the thesis including the rationale of the study, aims, research question and objectives of the PhD.

Chapter 2 initially presents an overview of dengue epidemiology worldwide, in the Americas and Colombia. Secondly, describes the characteristics of an effective *Ae. aegypti* control tool, along with measurements used to define effectiveness outcomes. Then, presents the experiences in scaling-up vector control interventions reviewing the process, the approaches used, and the challenges found.

Chapter 3 is a detailed description of the intervention including the description of the study area, the epidemiological data related to dengue and the local vector control programme. In addition, a Theory of Change (ToC) is presented to describe how the intervention activities were understood and produce the sequence of outcomes that influenced the intended and unintended impacts during the scaling-up.

Chapter 4 presents Study 1 related to the effectiveness of the intervention, using as secondary outcome different entomological indicators. A description of methods for data collection and analysis used in this study is presented.

Chapter 5 presents Study 2 related to the effectiveness of the intervention, using as primary outcome dengue cases. A description of methods used for data collection and analysis is presented.

Chapter 6 refers to Study 3. In particularly, it describes and analyses the process of scaling up and implementing "Girardot *Aedes-Free"* intervention. i.e. the factors of implementation success of the scaled-up intervention. In this thesis, scaling up refers to the process of expanding the coverage, and the adoption of a successfully tested intervention.

Chapter 7 addresses the success of the multisectoral collaboration/action approach built as part of the process of scaling-up the intervention (Study 4). It contains the results of the evaluation of the development and sustainability of a multi and intersectoral partnership. Particularly it focuses on the policy and organizational framework in which they act, how it functions, what the strengths and limitations are and how different sectors and individuals interact and how they were willing and able to involve and support and collaborate with local urban communities in their activities. Different management styles, ways of resource allocation, formal and informal institutional relationships, roles, which may facilitate or hinder the effectiveness of intersectoral collaborations, are presented. It also presents and discusses the findings of the multisectoral and intersectoral action process followed for the scaling of "Girardot *Aedes-Free"* intervention based on a mixed method approach.

In Chapter 8, the main findings concerning the research questions are summarized, discussed, and interpreted. General conclusions based on the findings of the studies presented in this thesis are described. The scope of the conclusions is limited to the local context of Girardot.

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Chapter 2 Background

2.1 Dengue

Dengue, a viral disease, is caused by one of four antigenically different *Flavivirus* serotypes (DENV-1, -2, -3, and -4) (1,2). Infection with a specific serotype confers subsequent immunity to that strain, however, susceptibility to other serotypes remains (3). In addition, infection with a new serotype can induce an aggressive immune reaction in immunocompetent subjects, which goes some way to explain why subsequent infections tend to be more severe and account for much of the mortality (3). Clinical manifestations of infection range from asymptomatic to rapid death from complications secondary to vascular leak and organ dysfunction (3,4). In 2009, the WHO redefined their dengue classification system following a multicentre systematic review reporting that 18% of cases were unclassifiable by experts into the old definitions of dengue fever (DF), dengue haemorrhagic fever (DHF), and dengue shock syndrome (DSS). A new classification was developed in order to detect a greater number of severe cases not meeting criteria for DHF, and the WHO now divides cases into "dengue +/- warning signs" and "severe dengue" (5).

The virus which causes dengue is transmitted by *Ae. aegypti* and *Aedes albopictus* mosquitoes when they bite (4). *Ae. aegypti* have been widely circulating in the Americas since the 1960s, and is rapidly expanding around the globe. This species is currently present on all continents except for the Antarctica (6). In 2015, Kraemer et al. studied the global distribution of these two important vector species, for *Ae. aegypti* more than 61% (11,737) of all occurrence records were from Asia and Oceania, 36% (6,857) were from the Americas and only 2% (433) occurrences were available from Africa and Europe (6). For *Ae. albopictus*, most of the occurrences were from Asia (75%, 16,125), 23% (5,141) from the Americas, and only 2% (n:893) records were available from Europe and Africa (6). Dengue has become a public health problem, considering the burden of the disease and the economic impact it brings to several areas of the Western Hemisphere (7).

Dengue can be conceptualized as "eco-biological-social" in nature and origin, with environmental, demographic, and social factors that overlap and reinforce each other. According to the epidemiological and entomological behaviour observed, *Ae. aegypti* has infested territories located below 2,000 meters above sea level, reaching very high rates of infestation in many urban areas (6,8–11).

Dengue transmission is very sensitive to changes in several of the dimensions of the ecosystem in which the transmitting vectors are present. This is how environmental factors such as rain, humidity, temperature, and the natural or human-created environment determine the presence and biology of the vector. For example, temperature has a combined effect on DENV development, as well as the survival of the transmitter vector (*Ae. aegypti*). With higher temperatures, the longevity of the vector is lengthened as well as viral incubation is faster so that the proportion of infected vectors increases (12–15). Models have determined that at temperatures below 20°C and above 34°C, *Ae. aegypti* cannot reproduce in substantial quantities, while within that range the incidence of dengue increases linearly (16–19). Likewise, precipitation has been positively correlated with *Aedes* reproduction rates and dengue transmission in many regions (20). Precipitation increases the number of potential breeding sites (natural or artificial) and larvae and pupal *Ae. aegypti* slightly affected by excessive rain (21).

Other risk factors for dengue outbreaks include the reintroduction of serotype 3, the simultaneous circulation of the 4 serotypes (1,22–24), the immune status of the population to each serotype, and the high human population densities in unplanned urbanization systems (25–27). On the other hand, the floating population derived from migratory flows (forced displacements, tourism, daily work, daily movement) of people over urban areas, is an important factor in the epidemiological dynamics of dengue (28–33). Several studies have evidenced the fundamental role of broad demographic and spatial structures in the initiation of growth and control of an epidemic. For example, Falcón-Lezama study (34) concluded that the key factors are local dilution, characterized by the vector-host relationship, and spatial connectivity characterized by the degree of movement patterns. Epidemic risk is driven by population groups that visit areas with the highest vector-host ratio, even if these groups remain for a short time.

In a systematic literature review that refers to the association between dengue and poverty (35,36), it was concluded that there are some positive associations between these variables (measures through income, education, the structural condition of housing, overcrowding, and socioeconomic status). Variables such as income and physical conditions of housing were more consistently correlated with higher dengue rates than other poverty indicators. This is how marginal and poor populations are exposed to difficulties in the availability and quality of basic services such as regular water supply and solid waste collection (37–40).

It is emphasized that the heterogeneity of the measures and scales used to capture the conditions of poverty used by the different articles makes it difficult to assess the strength and consistency of the landings between various indicators of poverty and dengue (36). In addition, the beliefs and practices of the community influence the level of domestic sanitation and determine the availability of places of production of immature forms of *Aedes* permanently established in the home environment (25,41–44).

2.2 Dengue global estimates

Estimates indicate that 390 million dengue infections occur every year (95% credible interval 284–528 million), of which 96 million (67–136 million) manifest clinically (with any severity of disease) (10). The regions most affected by dengue include the Americas, South-East Asia, and the Western Pacific. Particularly Asia accounts for around 70% of the global burden of disease (45). The incidence rate of dengue by country reported by the WHO is presented in Figure 2.1.

Figure 2.1. Worldwide incidence rate of dengue for 2017

Source: Dengue Data Application - World Health Organization (46)

2.2.1 Dengue in the Americas

Reported cases of DENV have increased 30-fold in the past 30 years, becoming highly endemic in the American region, with most cases ocurring in Brazil, Mexico, and Colombia (7,47,48).

In 2010, there were 1,598,334 dengue cases in the Americas reported to Pan American Health Organization (PAHO) (49) , in 2013, the number of cases increased to 2,347,042 (49), in 2015 to 2,403,523 (49), and in 2016 to 2,171,027 (49). By 2017, a significant decrease was recorded; a total of 579,027 cases were reported (49). Between 2018 and 2020, 6,078,582 dengue cases were reported (49). In particular, 2019 (3,190,778) was the largest epidemic recorded in the history of dengue in the Americas, exceeding by 30% the number of cases reported in the last epidemic year of 2015.

2.2.2 *Dengue in Colombia*

It is estimated that more than half of the Colombian population (about 24 out of 46 million people) live in areas susceptible to DENV transmission. *Ae. aegypti* is a widespread vector in Colombia below altitudes of 1,800 meters above sea level (MASL) (50). In Colombia, dengue is recognized as a disease that has increased in the last decades an endemic throughout most of the country. Different to other countries in the region, Colombia reports dengue cases throughout the year, and cases increase during rainy seasons (51). Dengue cases are reported in more than 66% of the municipalities of Colombia (50). Between 1999 and 2010, the majority of dengue cases concentrated in 18 municipalities, and 50% of cases were from capital cities, this indicates that the disease in Colombia is concentrated almost entirely in urban centres.

Between 1971 and 2010 there were 12 dengue epidemics in the country, leading to more than 1 million cases of dengue (annual average of 30,928 cases), and 7.4% of the cases involved severe dengue. Between 2011 and 2019, 711,381 dengue cases and 2 epidemics (2012-2013 and 2018-2019) were reported (52). In 2020, 78,979 cases of dengue were reported, and 897 of them were severe cases. Finally, in 2021, 53,334 dengue cases were reported, with 958 severe cases reported that year (49). A forecast of dengue cases expected in Colombia from 2019 through 2022 estimates that the situation will exceed the annual average from past years (annual average of 67,474 dengue cases) (53). Figure 2.2 shows the dengue incidence in Colombia between 1990 and 2021, it shows the multiple peaks mentioned before, with last of these occurring on 2019. Dengue cases and severe dengue cases appear to have decreased in the years 2020 and 2021, and the COVID pandemic's effect on underreporting is a likely cause.

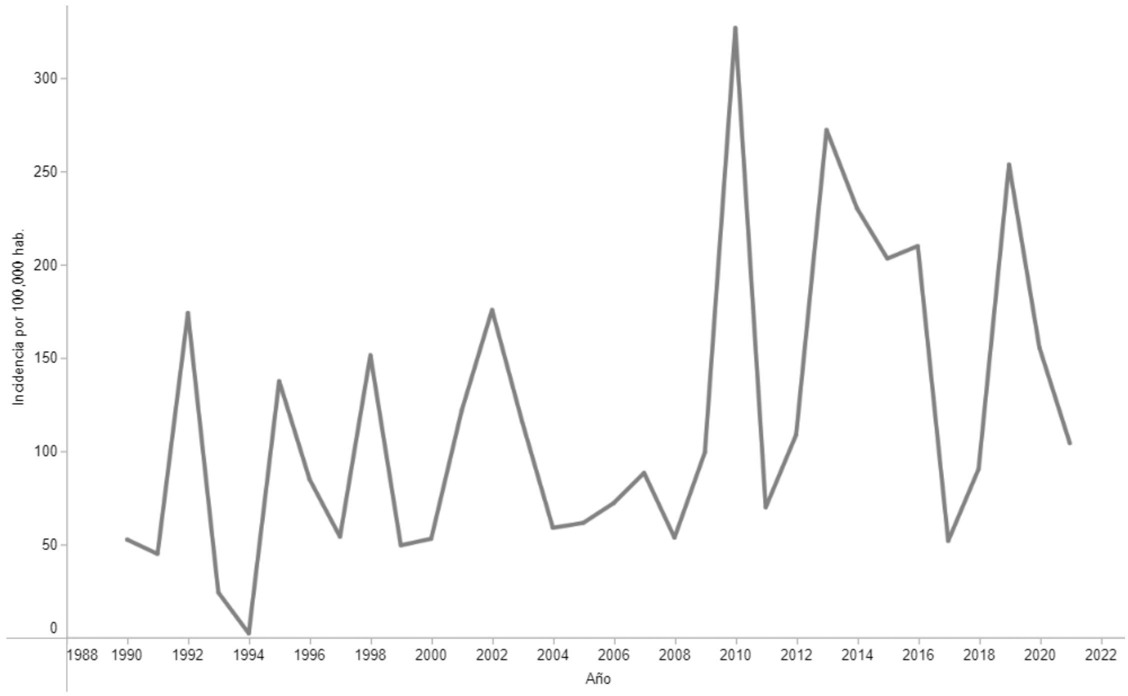

Figure 2.2. Dengue incidence per 100,000 inhabitants in Colombia, 1990-2021

Source: Health information Platform for the Americas (PLISA). Data reported by Ministries and Institutes of Health of the countries and territories in the Americas (54).

A systematic review reported that the age group most affected by dengue infections is the population under 15 years, and the disease affects similarly men and women (55). Simultaneous circulation of the 4 dengue serotypes have been reported in Colombia since 2004 (50). In the greatest dengue epidemic registered in Colombia (2010) so far, the distribution per serotype was described as: DEN-1 (43.8%), DEN-2 (40.4%), DEN-3 (12.5%), and DEN-4 (3.1%) (50). At a subnational scale, Figure 2.3 represents the six eco-epidemiologic regions in the country, classified by the predominant type of dengue transmission; Central-East Caribbean, Pacific coast, Central-West, Caribbean, Orinoquia, and Amazonian. Each region has its own conditions affected by local environmental, social, and cultural structures. The Central-East region is characterized by being hyperendemic due to intense and persistent transmission of dengue, with simultaneous circulation of three of the four dengue virus serotypes. In some of its municipalities, all four serotypes of the virus are in circulation (50). This region contains 6 of the 18 municipalities (Cúcuta, Bucaramanga, Neiva, Ibagué, Floridablanca, and Girardot) that displayed a greater concentration of cases between 1999 and 2010.

The Pacific Coast region is predominantly hypoendemic with overall low dengue transmission. However, it has a hyperendemic strip that corresponds to the province of Valle del Cauca, where three municipal capitals (Cali, Palmira, and Buga) display a focused behaviour of the disease.

The Central-West and Caribbean Coast regions are characterized as endemic-epidemic, with sustained transmission of dengue punctuated by epidemic outbreaks. However, both regions have urban centres in which cases are concentrated: Barranquilla and Valledupar (Caribbean Coast) and Armenia, Medellín, Pereira, and Dos quebradas (Central-West). The island territories of San Andrés and Providencia are characterized by hypoendemic behaviour.

The regions of Orinoquia and Amazonian have the same type of endemic-epidemic transmission in densely populated areas, as well as some hypoendemic, emergent, and re-emergent regions in the least populated areas. Only in the Orinoco region are there urban centres where dengue cases concentrate: the cities of Villavicencio, Arauca, and Yopal (Figure 2.3).

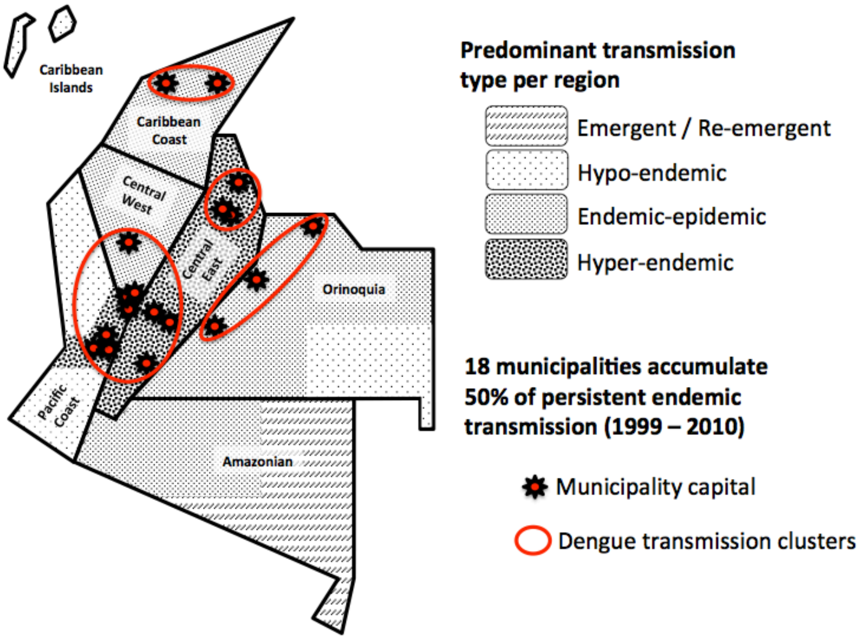

Figure 2.3. Eco-epidemiological regions of dengue transmission in Colombia

Source: Unpublished work (59: p.1.)

Four dengue concentrations are described in Colombia (Figure 2.3). One is in the central part of the country, which includes the urban centres of the hyperendemic areas of the Central-East and Pacific Coast regions, as well as endemic-epidemic areas of the Central-West region. The second group is concentrated in cities with the greatest number of cases of the Central-East region located in the country's northeast, on the border with Venezuela. The last two clusters are in endemic-epidemic areas, one in the Caribbean Coast region and the other in the Orinoquia region.

In the north and central parts of the country (Figure 2.4), there are dengue transmission clusters in eco-epidemiologic hyperendemic and endemic-epidemic regions respectively. Each capital city in these regions have at least 250,000 inhabitants, including urban metropolises of between 1 and 4 million inhabitants such as Barranquilla, Cali, and Medellin (57). The Caribbean region has the largest at-risk population (7,113,315), given that most of its population lives below 1,800 meters above sea level (50). The mobility of people in these areas is very high, due to secondary and tertiary economic activities and to migration flows among cities and from the countryside to the cities (including forced displacement), leading to the presence of belts of vulnerable conditions around the largest cities. The international border activity in this area is formal and controlled, since it is largely maritime and aerial.

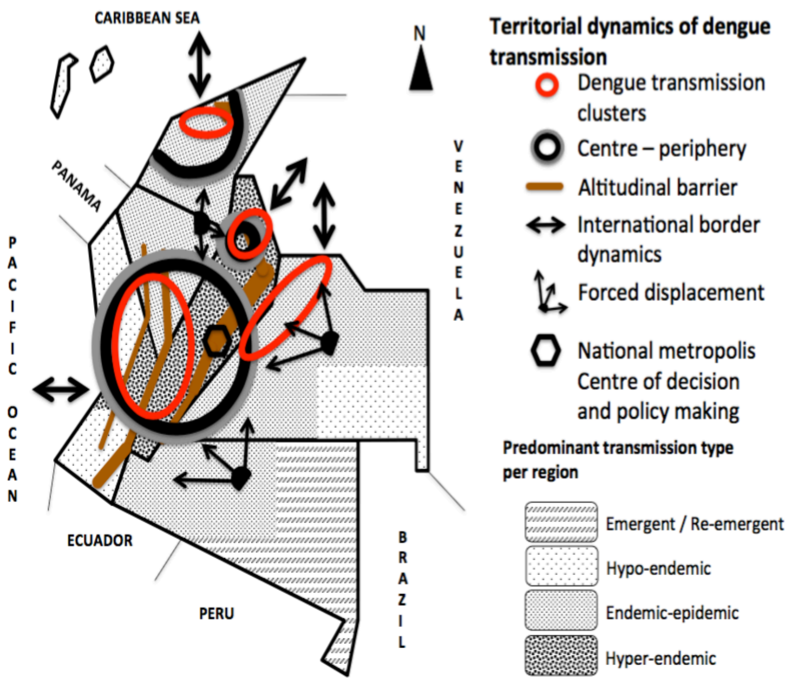

Figure 2.4. Territorial dynamics of dengue in Colombia

Source: Unpublished work (59: p.4.)

Another type of cluster occurs in peripheral areas where transmission is endemic-epidemic (Arauca, Yopal, and Villavicencio). The population at risk in this region (Orinoquia) is 1,127,396, and people's mobility is heavily affected by armed conflict (movement from rural to urban areas) and by extractive activities (exploration of minerals, oils and natural gas deposits).

In peripheral urban centres such as Arauca, where this cluster is located, international trade is important. The land border is permeable and allows easy transit, which is reflected in the importance of the informal economy and smuggling of many kinds, including everyday articles like foods, appliances, and gasoline. It is important to note that Villavicencio, located close to the central area of the country, features both central (international trade) and peripheral conditions simultaneously (armed conflict and extractive activities).

Finally, there is a cluster in northeast Colombia within the hyperendemic Central-East region. This cluster is divided by the eastern cordillera and simultaneously displays characteristics of the clusters of the central and peripheral areas noted above. On the one hand, it includes the central area of Bucaramanga and Floridablanca on the western slope of the cordillera, while on the other side Cúcuta shares the dynamics of the areas of the peripheral land borders noted above. Together, these cities accumulated more than 10% of the cases of dengue reported in Colombia between 1999 and 2010 (50).

2.3 Characteristics of effective Ae. aegypti control tools

There is a wide range of *Ae. aegypti* control intervention tools including: biological control, such as the introduction of larvivorus organisms in the water, insecticides to kill adults and larvae, and environmental management (source reduction, provision of safe water, covering of water containers, and reduction of human-vector contact by placing screens on doors and windows with insecticide-treated nets). There are also some methods that may become useful in the future such as the release of transgenic mosquitoes, or wolbachia infected mosquitoes (reducing or replacing the wild-type vector population with one that has reduced capacity to transmit and reproduce) (58,59).

Several systematic literature reviews (SLRs) on vector control interventions are available. Some reviews report single vector control interventions like Bacillus thuringiensis israelensis (Bti) (60), temephos (61), peridomestic space spraying (62), indoor spraying (63), larvivorous fish (64) and copepods (65), pyriproxyfen (66) and others consider more than one intervention. Below, a more detailed description of the results found in each of the SLRs that report more than one intervention is provided. Eight articles were assessed, of which four are meta-analyses, three are SLRs only and one is a meta-review. All studies have been published within the last decade. Tables A1-3 of Appendix A summarizes the main characteristics of the studies identified in the literature review, including the characteristics of insecticide-treated materials used as interventions.

Study designs range between randomized controlled trial, controlled clinical trial, longitudinal, control before and after, interrupted times series, case-control, cross sectional, retrospective observational, ecological, models, and quasi-experimental designs. This diversity in study design means diversity in quality.

Two categories of outcome measures were commonly used: entomological and disease transmission. The effectiveness of the interventions is measured mainly through entomological outcomes, that are determined through cross-sectional surveys carried out between weeks or months; few studies have tried to measure the effectiveness using human disease measures as outcomes.

The entomological measures used were not consistent. The most common entomological indicators used were the Breteau Index (BI), Container Index (CI), and House Index (HI). However, some studies also used larva stages (LIII, IV) as an estimate of adult density, pupal demography surveys (to measure interventions targeted at the most productive containers), tank positivity, ovitrap data, or number of mosquito adults.

To assess effectiveness, the studies used the mean difference between entomological parameters (between intervention and control or pre- post intervention data) or the relative reduction in vector density in relation to pre-intervention levels. Erlanger et al (67) used the measure of relative effectiveness (RE) defined as 1 minus the relative reduction of the measure (entomological index). RE: < 1 indicated a reduction caused by the intervention compared to control or pre post phase, RE: 0 indicated elimination of the vector population, and RE: > 1 indicated an increase in the corresponding measure in the target area. Furthermore, Ballanger-Browing *et al* used Mulla's percentage reduction (using Mulla formula 100-(CI/T1xT2/C2) x 100 that corrects for natural increases or decreases occurring in the control group that may have similarly affected the treatment group over time (67).

The degree to which the entomological parameters are reduced does not necessarily reflect the impact in the disease transmission as critical thresholds for disease transmission are unknown. The PAHO has proposed some values of BI, CI, and HI that categorizes the risk of transmission in three levels, high (HI >5%), medium (HI 1-5%), and low (HI < 1%) (68). Recently, the TDR suggested the use of pupal indexes based on pupal demographic surveys (69). This indicator serves as a proxy for adult density as it estimates the ratio of *Aedes* pupae to humans in a defined area and also allows the identification of the most productive breeding sites. In this case, thresholds for epidemic dengue transmission have been proposed based on different percentages of seroprevalence date and temperature of a certain setting (12).

The disease transmission measured in some of the studies used the number of serological /virological confirmed cases (seroconversion), dengue incidence rates, or reduction in odds of infection of dengue incidence. These outcomes also have some constraints as disease transmission is complex and is driven by diverse factors like human movements, number of susceptible individuals, and vector biting rates.

It is clear from the literature that the data collection, analysis and therefore interpretation, for both entomological and disease-related parameters are inconsistent. This makes the studies difficult to compare and makes it imposible to reach a definitive conclusion. Nevertheless, the literature provides insight into certain characteristics that can predict the effectiveness of the interventions: use of an integrated approach, use of community-based approaches, sufficient coverage, tailored to the setting (sociocultural, ecological), and community acceptance. But there is still a paucity of knowledge regarding the effectiveness in disease transmission (58,67,70–74).

In conclusion, the best practices in vector control remain to be defined for any setting (i.e., which tools or methods the community should employ), as well as what constitutes adequate or sufficient coverage in order to affect the vector population and virus transmission. This includes operational aspects, community mobilization, quality of delivery, and the most effective combination of interventions for successful vector control.

2.4 Scaling-up vector control interventions

The term of scaling-up has gained interest in the field of health interventions, particularly due to the global concern on successfully achieving the Millennium Development Goals (MDG) (75,76), replaced in 2015 by Sustainable development Goals (77). Worldwide, small-scale projects created to mitigate health problems have demonstrated outstanding results, nonetheless, most of them tend to remain in their original target areas and do not generate large-scale impact (78). This gap between the research and the implementation also occurs in the field of VBD.

Even though important progress has been made in the reduction of these illnesses (79), evidence-based programmes for effective control are limited for most vector-borne diseases and applied research is scarce in many settings, limiting the possibility of such evidence to inform on how to utilize and expand new tools, technologies, and approaches (80). Due to this, organizations such as the WHO have included in their response frameworks for scaling-up of integrated tools and approaches as a key action (81).

Scaling-up health interventions can be defined as the process of expanding the coverage and impact of a successfully tested health intervention, while accounting for future sustainability (82). The scaling up process considers different elements including the intervention type, the context where it is implemented, the resource team, the users that receive the intervention, the scaling strategy, and the pathway and mechanisms to achieve the goal (82–85). This process is opposite to spontaneous diffusion as there is an explicit intention to expand the reach of the innovation and it is guided by a systematic strategy to achieve this goal (82,86).

Typically, there are two types of scaling. Horizontal scaling is when an innovation is applied to another context or when new interventions are added to an already existing package in a population group. Vertical scaling, on the other hand, refers to the situation where a government decides to adopt the innovation at the national or sub-national level and it is institutionalized through planning mechanisms or changes in public policy (78,82,85,87).

A scoping literature review was performed to review and synthesise experiences on scaling-up vector control interventions with focus on describing the process and the approaches/theoretical frameworks used. The review also aimed to identify the barriers, key success factors and lessons learned to effectively scale-up the interventions. (See Appendix B for detailed description of search strategy and characteristics of reviewed studies).

The review identified case studies from Africa, Asia and Latin America. Overall, 14 (88%) case studies described the challenges for scaling-up malaria control in Africa and Venezuela, 4 (17%) were related to dengue control and 2 (8%) to Chagas disease control. All dengue and Chagas disease studies were conducted in Latin America (Colombia, Cuba, Mexico, Honduras, El Salvador, Guatemala, Uruguay and Brazil) (Appendix B).

The majority of the research was related to the expansion (horizontal scaling-up) of LLIN for controlling the malaria burden in Africa. There are few examples of analysis of the process of scaling up interventions. Most of the case studies report the type of scaling-up (vertical or horizontal) or the strategies for expansion (delivery) rather than the framework followed to implement the process of scaling-up or for the analysis of the process.

Chanda and collaborators, published the experiences from Malawi, Zambia, and South Sudan, describing the approaches used to scale up malaria vector control, the challenges encountered, the lessons learnt from these experiences, and how these were used to inform vector control initiatives (88,89). Table 2.1. illustrates the challenges faced and the lessons learnt from the interventions scaled for malaria control.

Table 0.1. Challenges, barriers, and lessons learned in the scaling of LLIN for malaria control

Challenges	Lessons learnt
Management:	
• Weak collaboration among the partners during implementation, monitoring and evaluation phases. • Lack of defined roles and responsibilities. • Lack of consensus among stakeholders on disposal mechanism for old LLINs. • Minimal collaboration between academic/scientific institutions and Ministry of Health on entomological resources, including insecticide resistance. • Limited collaboration with other vector borne disease control programmes. • Inadequate information sharing between stakeholders for timely decision-making.	• A nationwide campaign that is centrally coordinated and based on sound guidelines may offer greater benefits. • A strong partnership base and effective channels for the timely and supplementary deployment of LLINs may be essential if universal LLIN coverage is to be achieved. • Use of integrated approaches for substantial impact and optimal use of resources, a well-coordinated integrated vector management strategy may offer greater benefits. • Resistance monitoring and management plan involving all vector control resources.
Capacity /Resources:	
• Lack of operational research to guide informed decision-making. • Limited capacity for supportive supervision at state and county level • Limited number of entomologists • Minimal capacities for vector management activities. • Limited technical expertise on IVM	

- Lack of compliance with vector control distribution guidelines.

Political Context:

- Movements of refugees, returnees, and internally displaced persons
- Inaccessibility because of natural disasters and violence
- Delays in disbursement of funding from the Global Fund, primarily due to issues related to government financial management systems

Communication and information:

- Inadequate information and education or behaviour change communications and educational materials on LLINs.
- Inconsistent community sensitization and mobilization.
- Limited funds for production of Information Education Communication (IEC) materials.
- IEC messages are available in limited languages.

Community elements:

- Resistance by the population to use the nets and misuse of the nets for fishing or fencing.
- Leakage of distributed LLINs into the market.
- Influx of untreated nets and other recommended types.
- Low ownership of LLINs by vulnerable groups.
- Conditions of households predispose the LLINs to heavy wear and tear, Inconsistencies in distribution campaigns.

There have been even fewer efforts to scale up effective interventions for controlling other VBD (dengue and Chagas disease), as well as for analysing the process of scaling-up the interventions. The most recent study analysed the scaling-up processes of six Ecohealth projects in Latin America (Mexico Colombia, Guatemala, El Salvador, and Honduras (56). The study aimed to identify the key elements recognised directly by project stakeholders for the successful development of the expansion of the interventions. Guatemala, El Salvador, and Honduras scaled-up interventions for Chagas disease prevention, while Mexico and Colombia for dengue prevention. The following were identified as factors that influence the process of scaling-up an intervention: 1. Strategies for scaling up including the type of innovation, management and resources and community participation, 2. The political and the geographic context where the scaling was implemented and 3. Outcomes or consequences derived from the process. This includes the impact on people and institutions, institutionalization of the interventions and the coordination between public and private institutions.

In addition, a study conducted in 2015 in Central America (El Salvador, Honduras, and Guatemala) (90) reports the results from the scaled up systematization of a Chagas disease vector control intervention that involved recording the stakeholder experiences, understanding contextual characteristics and determining project findings. In 2004, a Chagas disease control intervention based on the sustained used of local materials was implemented in Guatemala under an Ecohealth approach (91). The intervention involved the improvement of adobe and "bahareque" houses (built in wood, mud, and thatched roof, similar to wattle and daub) through the use of local materials to cover cracked walls and dirty floors as they were the main risk factors for vector infestation. After testing the efficacy through the decline of vector re-infestation and human blood ingestion the intervention was scaled-up in 2011 in the bordering regions of Guatemala, Honduras, and El Salvador (92). The scaling-up process involved not only enhancing the intervention impact but also determining whether the intervention could be applied to other ecological, ethnic, and cultural contexts. The analysis of the scaling process of identified the following key factors and challenges for scaling-up are then highlighted in Table 2.2.

Table 0.2. Challenges and lessons learned in the scaling of Chagas disease and dengue control interventions in Latin America

Challenges	Lessons learnt
Context	*Intervention*
Political	
In rural context, civil wars, and illegal economic activities as gold mining. Long overall absence of the government, resulting in its projects being replaced by national and international private agencies.	The type of intervention was considered fundamental, as interventions scaled up differed from the current interventions regarding its content, resources and management. Multipurpose interventions that aimed beyond controlling the vector to impact the quality of life.
Setting	
-Rural: Not existent, or poor quality of roads requiring air or fluvial transportation for field activities.	*Community participation*
-Urban: (mainly dengue projects), insecurity and violence were present. Rejection for households' surveys and implementation of intervention due to insecurity.	Active community participation is essential for the development of the interventions. Use of several participatory methods Interventions with an educational component produce greater motivation and behavioural and attitude changes in community members.
People´s perceptions Problems are exclusively seen as part of the health sector and of government responsibility during outbreaks.	In interventions where people learned, and applied techniques of housing improvement (Central America) greater appropriation of the intervention was achieved.
Political instability, high turnover of stakeholders, decision-makers, and personnel from public institutions	*Paternalism vs community autonomy:* communities used to paternalism opportunely accept the intervention, but its appropriateness is slower.

No intersectoral coordination No harmonisation between local and national policies.	*Intersectoral collaboration* Given the multipurpose objective of the interventions, different institutions were able to work together and scaled the interventions by their own means. Difficulties in making public policy instruments transcended the health sector. *Leadership* In general, it was agreed that the participation of the government can facilitate the processes of scaling, but if this is not possible, it can also be led by other actors. *Institutionalization of the intervention* Lack decision-making in government for the adoption of an intervention at national or sub-national levels Progress was reported in relation to the involvement of some local officials and leaders, who had greater proximity to the intervention, but without reaching the institutional level proposed by vertical scaling-up.

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Chapter 3 Girardot *Aedes-Free* intervention

3.1 Outline

This chapter describes the intervention under study, "Girardot *Aedes-Free*". First, it provides the general context in which "Girardot *Aedes-Free*" operated, with epidemiological data related to dengue and descriptions of important dengue and vector prevention and control frameworks. Secondly, it goes into detail concerning the core components of the intervention and its local implementation. The theory of change is presented to describe how the intervention activities were understood.

The context, process and outcome evaluation model proposed by Fridrich, A. et al. (1), The modified theoretical framework to assess implementation fidelity of adaptive public health interventions by Perez, D. et al. (2) and the Template for Intervention Description and Replication for Population Health and Policy intervention (TIDieR-PHP) guidelines for reporting population health and policy interventions (3) were used characterize key features of the intervention such as duration, intensity, modes of delivery, processes, monitoring and context—all of which are essential, specific descriptors for intervention process evaluation. Data from several sources (protocol and study reports) were synthesized to build the theoretical model around the different intervention components. The theoretical model was planned to be constructed in a participatory manner with the involvement of the research team and other stakeholders to arrive at a final consensus-based model, but due to COVID-19 pandemic constraints, this could not be achieved. Consequently, I constructed the theoretical model based on my own analysis of all project logs.

3.2 Context

3.2.1 Study area (Girardot-Colombia)

"Girardot *Aedes-Free"* intervention was scaled-up in Girardot, a municipality located to the southwest of the province (department) of Cundinamarca in Colombia. Girardot is the largest and most important municipality in its province. It is at 289 meters above sea level (MASL), has an area of 130 km^2, a total population of 104,476 and a population density of 821,68 hab / km^2 (4). It is characterized by a bi-modal rain regime (two rainy seasons from March to May and from October to November) and has a mean precipitation of 1220 mm, a relative humidity of 66.4% and a mean temperature of 33.3 °C (5,6). Girardot is divided into five urban communities: 1. Center (15 neighbourhoods); 2. South (16 Neighbourhoods);

3. The West (36 neighbourhoods); 4. North (42 neighbourhoods); 5. East (24 neighbourhoods)—and two rural zones: 1. Barzalosa and 2. San Lorenzo.

Girardot's main economic activities are retail (58%), services (mostly restaurants and bars (36.5%), and hotels and hostels (10%). Girardot has earned a reputation as a "tourist city" for residents of Bogotá (capital of Colombia) mostly because of its tropical climate. The population can increase by three times its usual size during brief intervals like extended weekends and vacation times (7,8).

There is a clear division of non-residential land uses (university campus, undeveloped lands, and sport complex). Block shape, extension, and orientation of the residential areas are varied and fragmented (by parks and undeveloped terrains) but well connected by main streets (Figure 3.1).

Figure 3.1. Urban Morphology of Girardot

Source Gabriel Leaño

The conditions of residential areas can be described as a mixed pattern of official and informal residential dwellings, as well as second residential dwellings (used only on weekends or vacation times). Low socioeconomic strata homes tend to cluster along the banks of the Magdalena and Bogotá rivers, while more formal habitation is found closer to the city center. A collection of new structures (from various socioeconomic strata) are situated near the western boundaries of the municipality. Nearly half (49.5%) of the population owns their home; the remaining residents either rent, sublet, or lease their homes (9)

More than half (80%) of the population inhabits households from socio-economic strata 2 and 3 followed by stratum 1 according to the socio-economic stratification system of households' physical characteristics (land use, public utilities, access to routes) and geo-economic aspects (land valuation) of dwellings (10, 11). This system proposes 6 socio-economic strata, 0 being the lowest and 6 the highest. The main purpose of this stratification is to set various rates for public services in accordance with the solidarity principle with residents in high stratum (strata 5 and 6) paying higher rates to subsidise residents of lower socio-economic status (strata 1 to 3) (12). In Girardot access to public services is not a major concern, reporting an important coverage of domestic piped water supply (65.3% in strata 1 and over 80% in strata 2 and 3) (10,11). Figures 3.2 A, B and C illustrates the physical characteristics of residential areas per stratum. It can be depicted mainly good housing conditions. Predominantly residential areas of some multi-story buildings. More over 80% of the one-story dwellings had backyards, and most had glass windows and indoor flush toilets. Recreation and green areas are frequent. It is important to notice that stratum 1 residential areas are concentrated following the Magdalena's and Bogotá's river banks and are more likely to be informal settlements.

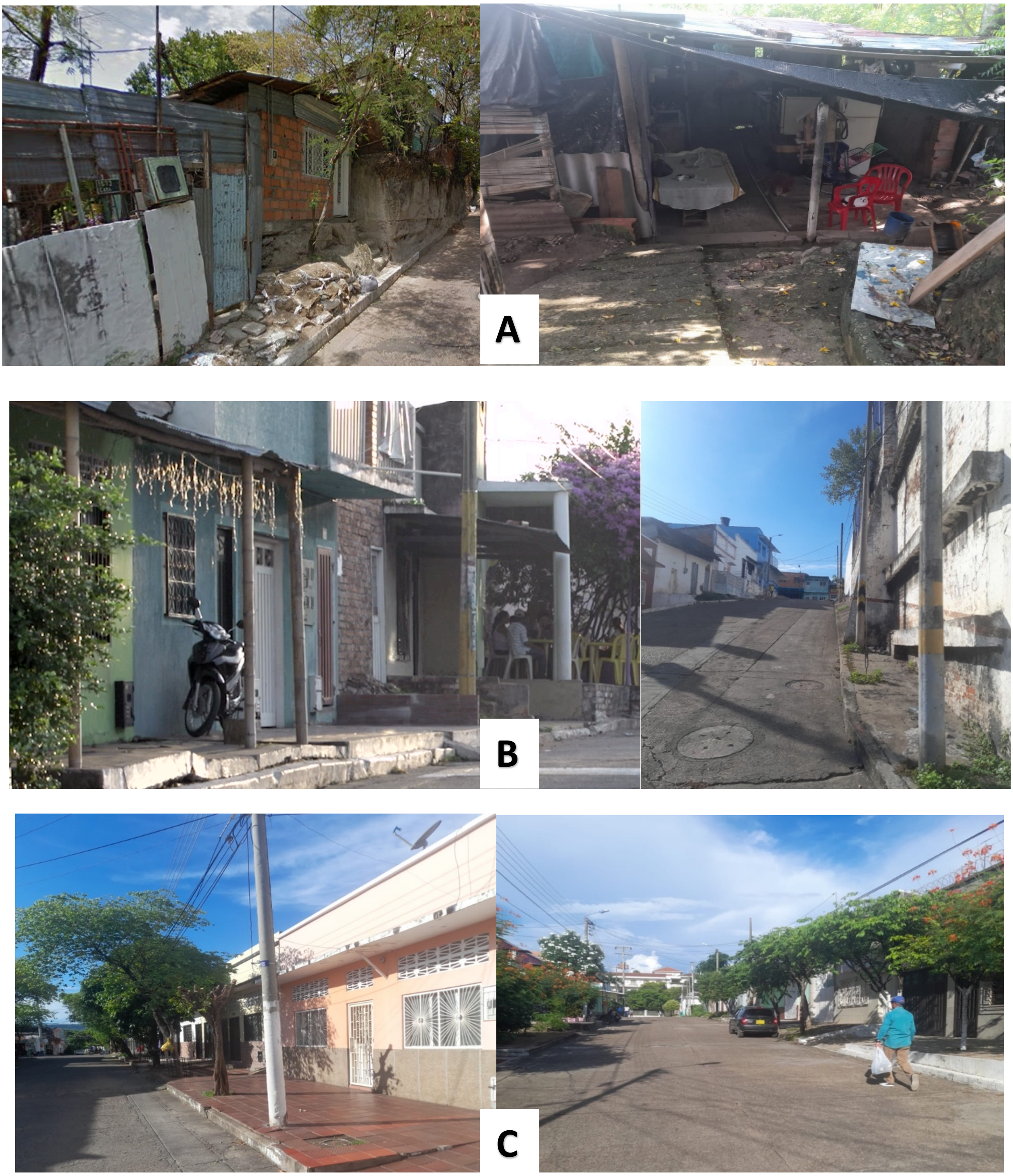
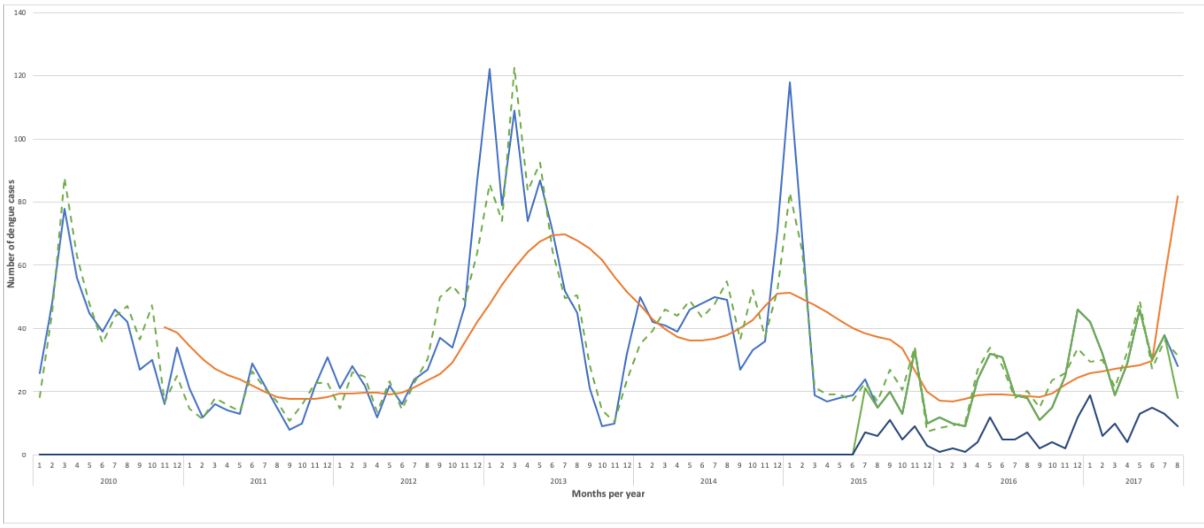


Figure 3.2 Physical feature of dwellings and streets representing socio-economic strata 1 (A), strata 2 (B.) and strata 3 (C)

3.2.2 Dengue epidemiology of study area

Between 1999 and 2010, dengue cases were reported in more than 66% (1,112) of the municipalities of Colombia (13). The Colombian state of Cundinamarca has been recognized as one of the most prevalent areas for the DENV, with DENV endemic in 84% (48/57) of the municipalities. In four of these municipalities DENV was hyperendemic, and Girardot accounted for 30.9% of dengue cases in Cundinamarca with all four DENV serotypes circulating (14). It was one of the 18 Colombian municipalities that, between them, accounted for 50% of dengue cases during the period 1990 to 2010.

Between 2010 (1st epidemiological week) and 2017 (33rd epidemiological week, end of the study period), 3,193 suspected dengue cases were reported to the surveillance system of Girardot, of which 99.6% were clinically classified as dengue. During this period a mean of 1.93 dengue cases were reported per day (range 1 to 14) although only 198 (6.2%) were laboratory-confirmed. Figure 3.3 shows three outbreaks over the course of 8 years. During 2010, 487 dengue cases were reported, 708 cases in 2013 and 532 in 2014 (14).



Blue line: number of dengue cases; green dashed line: deseasonalized frequency; orange line: central moving average; solid green line: number of dengue cases during study period; dark blue line: dengue cases per study sectors 1 and 2.

Figure 3.3 Number of reported cases in Girardot, Colombia 2010- 2017

Slightly more men than women were affected by dengue (1690, 52.9%). The mean age for dengue cases was 21.6 years (Figure 3.3). More than half (55.3%, 1768) of dengue cases were under 16 years old. The age-groups that reported higher dengue cases were those between 0 and 5 years old (587) and 6 and 10 years old (720) (Figure 3.4).

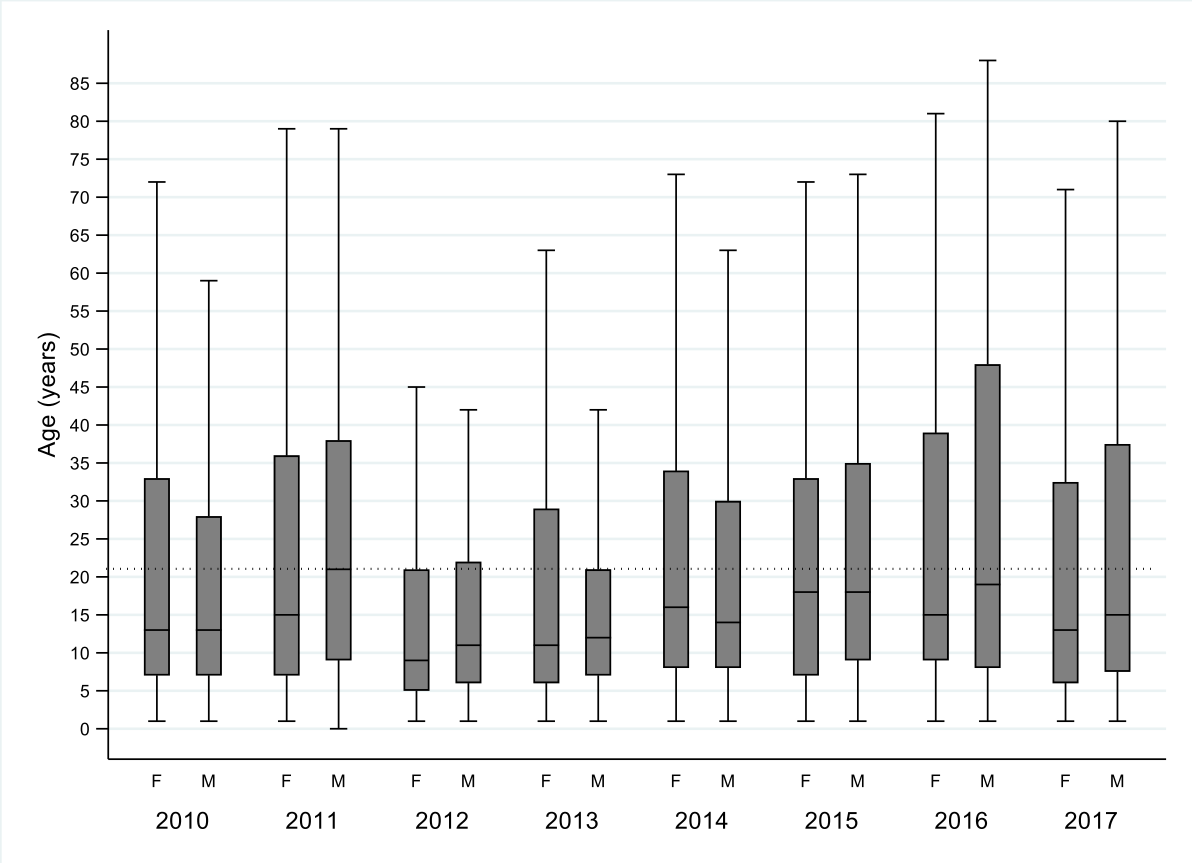


Figure 3.4 Distribution of reported dengue disease cases according to age and sex, Girardot, 2010-2017.

In addition, as Girardot presents an eco-epidemiological and social niche propitious for a sustained transmission of dengue (15,16). Other *Aedes*-borne transmitted diseases—Chikungunya and Zika— (17) have also recently circulated there.

3.2.3 Aedes aegypti in Girardot

Ae. aegypti has been reported by different local studies as the principal vector in the municipality of Girardot (15,16,18). The studies carried out report a PPI over threshold transmission levels (PPI: in wet season 1 and in dry season 1.3), and a Breteau index above risk levels (in wet season 39.8 and in dry season 29.2) (18). *Ae. aegypti's* productivity is mainly associated with storage of water in uncovered large cement containers known as 'albercas' and accounts for more than 70% of the pupal production (18).

In studies about water storage in Colombia, an association was found between the householder occupation and the method of storage (OR: 2.6, 95% CI: 1.5–4.3). People who have been informed about actions to prevent dengue (OR 1.7, 95% CI: 1.02–2.87) are less likely to store water (19).

A study conducted in Girardot by Garcia-Sánchez, D.C. et al. (20) demonstrated that the establishment of habitats for immature *Ae. aegypti* in the most productive container (albercas) is regulated by biotic and abiotic factors and interactions between these factors. The authors showed that the occurrence of detritus was greater and the container volume was smaller in the tanks that were positive for larvae and only Cyanobacteria had a positive correlation with the abundance of immature-stage *Ae. aegypti.*

3.3 Vector control frameworks

Vector control programmes are defined as priority diseases and a Ten-year Public Health Plan 2012-2021 (21) dictates that each territory must implement the Integrated Management Strategy (IMS) for the surveillance, promotion, and control of VBD (22). Vector control programmes in Colombia are operated through a central programme coordinated by the Ministry of Health and Social Protection (MoH) and are operationalized at subnational levels (provinces, district, or municipalities) programmes as established by the Law 715 of 2001 (23). Law 715 of 2001 defined the allocation of responsibilities and resources consistent with a territorial categorisation. Subnational entities are classified into six categories, according to their population, tax revenues, economic importance and geographical location (category 1 with highest population (more than 100.000 inhabitants) and tax revenues and category 6 with lowest population (less than 10.000 inhabitants, and less tax incomes). Therefore, municipalities in categories 1, 2 and 3—if certified by the MoH—have the autonomy to receive and directly execute the financial resources to develop their prevention and control programs. Category 4, 5 and 6 municipalities are province-dependent for both the allocation of resources and the execution of the VBD programme. Girardot is category 1, therefore has the autonomy to plan and execute VBD actions (24).

Funds for the operation of the VBD programmes are transferred to territorial entities by the MoH through the General Participation System (SGP) (23). According to Articles 356 and 357 of the Political Constitution of Colombia, as amended by Legislative Acts 01 of 2001 and 04 of 2007, the General Participation System corresponds to the resources that the Nation must transfer directly to the territorial entities (provinces, districts, and municipalities) for the financing of the services they are responsible in education, health, public services, housing, agriculture and livestock, transportation, environment, prisons, and sports. In terms of sectoral distribution, 58.5% is allocated to education, 24.5% to health, 5.4% to potable water and 11.6% to general purpose or other sectors.

With respect to the health component, the MoH allocated and distributed the SGP resources in the following components: 1. 87% for the health insurance component for affiliates of the subsidised regime (people without payment capacity) and 2. 13% for the Public Health.

For VBD resources are used to cover costs for personnel and consumable resources. The budget does not make allowance for the use of chemical products, that are supplied when necessary (during outbreaks) by the province of Cundinamarca.

The IMS for dengue in Girardot (22) was implemented in June 2013 after an outbreak of dengue earlier that year. This strategy emphasizes daily (rather than weekly) notification of cases by health institutions, the use of mosquito nets as an outpatient management strategy, training of health staff in the clinical management of dengue, and serology testing for the detection of anti-dengue antibodies (IgM) in all severe dengue and dengue cases with signs of alarm, as well as in 10% of dengue cases.

3.4 Vector control interventions in Girardot

3.4.1 Local vector control programme

In Girardot, as is the case for the rest of Colombia, the local programme uses the epidemiological and entomological information available to evaluate, identify and prioritize risk areas to implement vector control (25). Vector control in Girardot, while limited, is conducted through the integration of several approaches (25). Control efforts include sporadic vector suppression, based on monthly entomological surveillance data, with ULV fogging machines. There is also widespread application of temephos in water containers as a larvicide. Source reduction is conducted by designated technicians at the local municipality level and complemented by mobilization of communities to assist with environmental sanitation (elimination of mosquito breeding sites). Although few have been launched, behaviour change campaigns are another element in the fight against *Ae. aegypti*. During the Zika outbreak in 2015/16 that affected several countries in South America, Girardot focused its efforts on risk communication and community mobilization. They launched “Familias que transmiten vida”, a strategy to control hotspots, raise awareness among communities and engage them in the elimination of breeding sites (26–28).

The Health Secretariat has a Public Health office and an Epidemiology division that are responsible for surveillance, control, situational analysis, and planning of VBD interventions. The guidelines for VBD interventions are defined in the “Plan de Intervenciones Colectivas (Plan of collective interventions)”. The VBD control program has 14 officers: 2 social workers, 11 VBD technicians and a coordinator (Environmental engineer). The social workers support educational activities with community leaders, school boards and other closed community groups. VBD technicians, with the support of health promoters, oversee regular activities (daily households visits) to calculate traditional entomological indexes. In addition, in the presence of any dengue case, they carry out focused visits. The coordinator monitors all activities performed. Public health and epidemiology officers give the coordinator a weekly list of reported cases to be visited.

For carrying out vector control activities, Girardot has been divided into 8 sectors. Each sector corresponds to approximately 15 neighbourhoods. Each technician and or social worker is assigned to a sector and must make daily visits to 40 houses (200 weekly visits).

The regular activities of the VBD programme are carried out daily and consist of inspection of the house for water-holding containers, calculation of entomological indexes, distribution of temephos in ground tanks, health education (how to wash tanks and collect all potential breeding sites) and communication activities (television and radio slots transmitted by the municipality TV channel). Focused visits are carried out weekly, according to reported cases. In the presence of a positive case of severe dengue, the household is inspected, as well as six blocks around the positive case. This corresponds to approximately 40 houses. If an increase in entomological indexes is evidenced, indoor and outdoor space spraying with malathion of houses and public spaces is performed.

3.4.2 "Girardot Aedes-Free" Intervention

A key feature of the Girardot *Aedes-Free* intervention under study here is that it was delivered collectively to the population of sectors 1 and 2 (Figure 3.1.) and can be defined as a complex community-based intervention (29–32), where different components interact at different levels (household, school, community and institutional/sectoral)within the community where different actors interact and participate.

Intervention levels

At the household level, the actions consisted mainly of implementing insecticidal covers for large water-holding containers that were previously designed through workshops within the community as described in Garcia-Betancourt et al. (33) and tested for its acceptability, uptake and efficacy as presented by Quintero et al. in 2015 (34).

The ITCo for large water containers were made of PermaNet (Vestergaard-Frandsen, Denmark), factory-treated with long-lasting insecticide formulation of deltamethrin (50 mg/m2). The covers were a standard white and blue colour and were developed from pre-packaged curtain or bed-net material. Figure 3.4 shows two types of covers—Photographs A: the water container cover for rectangular or square cement containers of at least 200 L capacity (this cover is made of an aluminium frame, LLIN and a sliding mechanism for opening both doors tailored according to the different sizes and shapes of the water tanks); and Photograph B: the circular water cover for plastic containers (this cover is made of LLIN and rubber attached to a waterproof fabric for plastic and cement cylindrical containers that can store more than 200 L (Figure 3.5 A and B, and Appendix C2) .

A: Aluminium frame water container cover B: Circular cover

Figure 3.5 A and B. Types of Insecticidal container covers

The design, manufacture, and installation of the rectangular insecticide-treated metallic covers (IMC) was carried out in collaboration with a local small business, and three dressmakers made the circular insecticide-treated covers (CIC)—in each case supervised by the research team. Six criteria were indicated by the research team for the construction of the covers (Table 3.1).

Table 3.1. Criteria for the design and manufacture of Insecticidal container covers

Criteria	Description
User friendly	Designed lids should be easy to use by all house members.
Fixed installation	The lid must be fixed, it must not be removed, although it must be able to be opened and closed, either with side opening, folding, or sliding. (See photographs and diagrams in Figure 3.4 A and B)
Easy container cleaning process	The cover design should allow for an easy water-holding container cleaning process. (The tank opening with the lid installed and fully open should be, as far as possible, equal to the initial water-holding container opening without the lid installed.
Durability	The quantity and quality of the installed materials should be such that the tank lid will last as long as possible—in particular, rust-proof hinges, screws, and rivets should be used.
Space tight	The lid should prevent the vector from entering to lay eggs.

Alongside the implementation of the water container covers within households, information, education and communication (IEC) activities were conducted concerning the prevention of breeding sites, the washing of water-holding tanks and the care and appropriate use of the covers.

Two schools were involved—Instituto Kennedy and Institución Educativa Policarpa Salavarrieta—both located in Sector 1 of the study area of the study area corresponding to socioeconomic strata 1 to 3. Teachers, parents, and students from tenth and eleventh grades of both institutions were invited to participate in three information and educational workshops: 1. Design and development of screens for classroom doors and windows (13 participants), 2. Mosquito identification and myths regarding arboviruses (30 teachers and parents), and 3. Design of a prevention and control measures information banner (17 participants).

In addition, 14 students from Institución Educativa Policarpa Salavarrieta under the mandatory social service participated in community mobilization, IEC activities and entomological follow-up visits in households and public spaces during the introduction of the insecticide-treated container covers in households.

Community-based actions were principally focused on enhancing the participation of the leaders of the local community action boards by involving them in the intervention areas and encouraging them to join efforts to streamline and implement intervention actions in families, as well as to spread the importance of addressing the vector control actions.

At the sectoral level, work was done on shaping and strengthening the political will of the different municipal sectors and actors, towards the prevention and control of VBD. This work resulted in the creation of a multisectoral and intersectoral committee (MSC) for the promotion, prevention and control of VBD through a municipal agreement promoted by the Municipal Secretariat of Health (MSH) on September 7, 2017 (35) (Figure 3.6). The health, tourism, education, infrastructure, planning and financial sectors of the municipal administration were all involved in the committee, as well as representatives from the private sector, civil society, and community leaders. A steering committee was created, and goals and objectives were established, with the project research team serving as primary coordinators. Diverse sectoral actions were proposed and are detailed in Chapter 7 which addresses the development and sustainability of such multisectoral and intersectoral action collaboration.

Figure 3.6. Multi and Inter- sectoral committee members and logo type

All implementation activities at all intervention levels were coordinated and carried out by a multidisciplinary research team composed of 1 field supervisor, 1 field coordinator, 4 field technicians (environmental engineers), 1 social worker, 14 school students and 8 researchers from different disciplines (epidemiologists, anthropologists, environmental engineers, business administrators, biologists, and entomologists).

Intervention areas

Girardot was divided into 4 sectors (Sector 1 – Sector 4) (Figure 3.7 A). A sector was defined as an area that includes several neighborhoods with similar physical and sociodemographic characteristics. The spatial and social unit of the intervention was a neigborhood. A neighborhood was defined as a differentiated territory that shares physical (urban morphology), historic and social characteristitcs and has its own dynamics. Each sector was divided into intervention, buffer (100 meters) and control zones. Intervention zones included clusters from the previous Cluster Randomized Control Trial (cCRT). The intervention was implemented in Sector 1 (Kennedy) that included 4 clusters of the previous cCRT (3 control clusters and 1 intervention cluster), and in Sector 2 (North) that included 5 clusters (2 intervention clusters and 3 control clusters) that corresponds to socio-economic strata 1 to 3 (according to the physical characteristics of the dwellings, streets, including construction materials and access to basic infrastructure public services). Furthermore, the majority (81.6 %) of householder's report household income between one and two minimum wages (US$ 276= 1 minimum wage) followed by 11.6% that report household income lower than one minimum wage.

Due to their correspondence to the lowest socio-economic strata, the research team and health officials chose to begin implementing the intervention in these two sectors. Tables 3.2 and 3.3 present the characteristics of both sectors, comparing intervention and control areas.

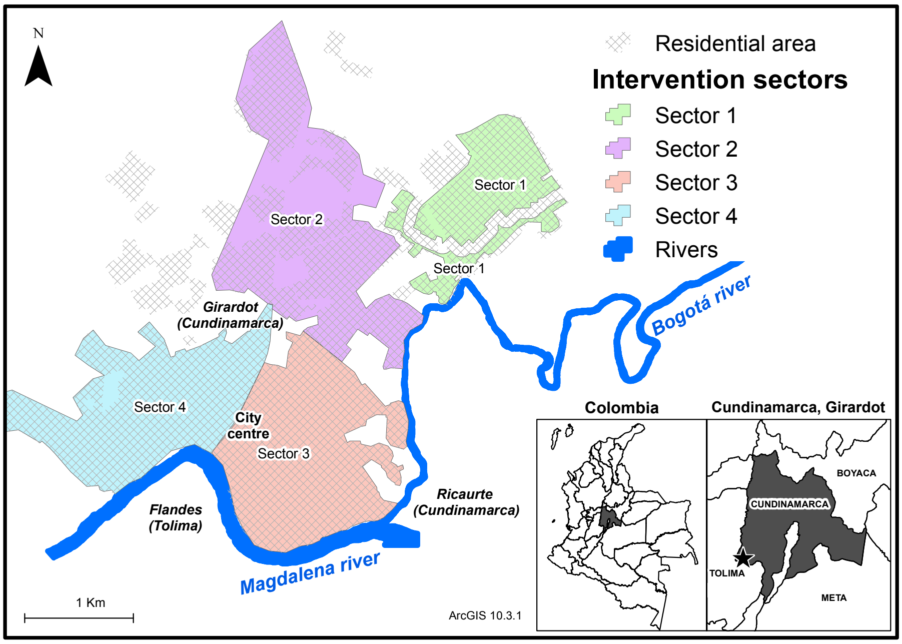


Figure 3.7 Map of Girardot and study sectors

Table 3.2. Characteristics of Sector 1 "Kennedy"

Characteristics	Total of the area	Intervention	Control
Number of clusters from previous CRT	4	4*	0
Number of households	4090	2087	2003
Number of sampled households (minimun 33% of household with albercas)	1350	689	661
Number of entomological surveys	1350	689	661
Households followed-up	723	343 (49.7%)	380 (57.5%)

*3 control 1 intervention clusters

Table 3.3. Characteristics of Sector 2 "North"

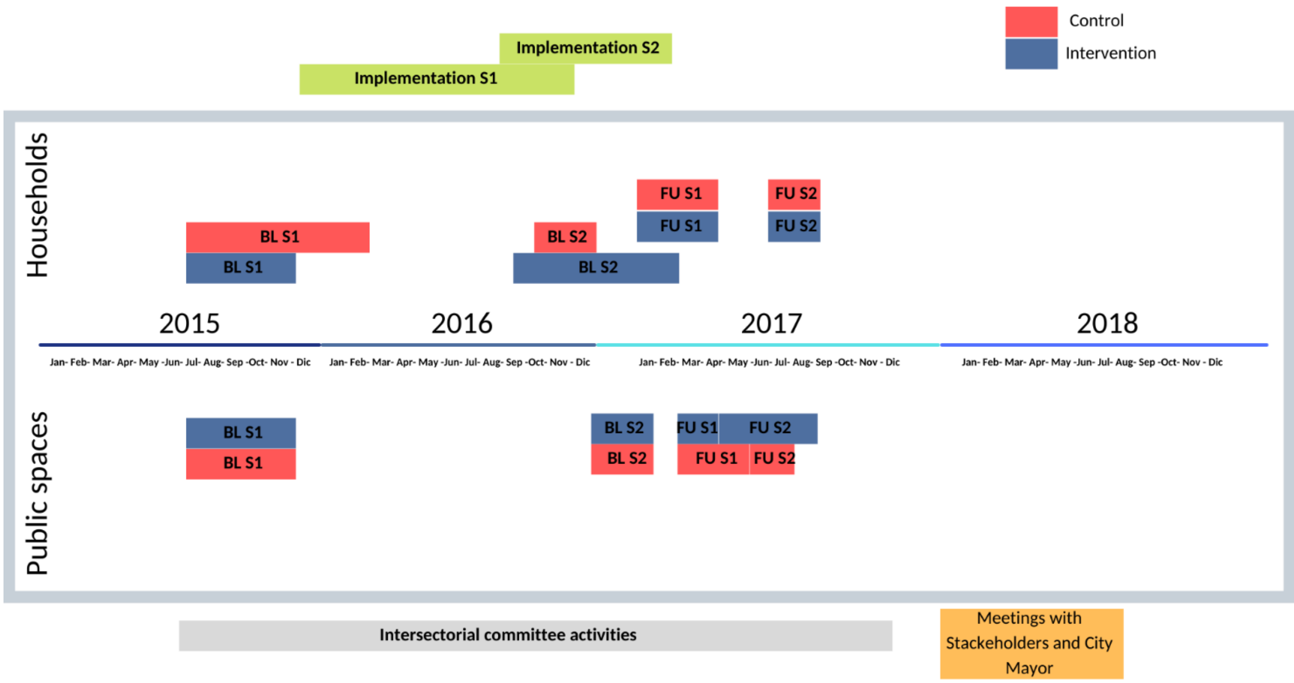
Characteristics	Total of the area	Intervention	Control
Number of clusters from previous cCRT	5	5 *	0
Number of households	4832	3502	1330
Number of sampled households (minimum 33% of household with albercas)	1321	1155	291
Number of entomological surveys	1319	1030	289
Households followed-up	510	424 (51.2%)	86 (295.5%)

*2 intervention 3 control clusters

Implementation phases

The scaling-up of "Girardot *Aedes-Free"* encompasses three distinctive phases that have been proposed in intervention evaluation models/frameworks: 1. Pre-implementation phase (planning and setting-up of activities); 2. Active implementation (action phase); and 3. Sustainability or appropriation phase (1).

"Girardot *Aedes-Free"* intervention took place between July 7, 2015, and July 27, 2018. Figure 3.8 shows the period of time time when study activities ocurred.



*BL: Baseline; FU: Follow up; S1: Sector 1; S2: Sector 2

Figure 3.8 Timeline of scaling-up implementation phases of Girardot Aedes- Free intervention

a. Pre-implementation or set-up phase *(2015)*

Consisted of identifying the target population, adopter audiences, key partners, initial spread of the intervention and communication strategies. During this phase the research team was consolidated, the type of study design was defined (quasi-experimental with control group), and intervention and control areas selected. Actions aimed at building coalitions with local stakeholders and authorities were initiated through a multisectoral workshop conducted over two days, July 22-23, 2015. Preliminary objectives and goals were set during this workshop.

Diverse communication materials were discussed and designed for different audiences as tools to promote and support intervention socialization, VBD prevention and control awareness (Table 3.4) (See Appendix C, Table C-1). The communication materials were implemented mainly in the implementation phase described later.

Table 3.4. Information and communication materials

Material	Description	Target audience
Three bulletins or newsletters	Short statements of news about project activities and general health recommendations. The document was divided into 5 sections: Project progress; Voice from the community; VBD prevention and control measures; general health recommendations; and future project activities.	Community members and key partners
Two brochures	Including critical information about the details of the intervention and products and services provided by the project.	Key partners: national, regional, and local authorities from different sectors.
461 almanacs	Annual publication listing a set of current information about dengue and vector control activities developed in conjunction by research team and State Secretariat of Health	Household members
1580 information sheets ("tapa y lava la tapa")	Providing information about proper use and care of covers.	Household members
40,000 Flyers	Providing information about recommendations for *Aedes*-related diseases prevention and control measures	Tourists at hotels and land transport terminals.
28 Posters	Printed sheets containing information about project activities, number of covers installed and contact data,	Community members

	posted in public spaces of study sector neighbourhoods	
1 School banner: "*Aedes-Free School*"	Graphic piece embodied on a wall that provides information about guidelines for *Aedes*-related diseases prevention and control	Teachers, parents, and students from Instituto Kennedy

b. Action phase or implementation phase (2016-2017)

Monitoring occurred throughout the action and implementation phase. The enactment activities principally focused on the installation of water container covers and the establishment of the MSC along with the implementation of the communication materials designed in the pre-implementation phase.

Covers were installed in the period December 4, 2015 through to February 24, 2017. On average, 1.5 covers per premises were installed that corresponds to 63% of premises in sectors 1 and 2 (Table 3.5).

Table 3.5. Number of insecticide-treated container covers installed per sector

	Sector 1	Sector 2	Total
Total of premises	2625	3502	6127
Premises reached for installation	2086	1750	3836
Premises with albercas	2083	1744	3827
Number of albercas	2165	1796	3961
Number of aluminium covers installed	2148	1786	3934
Round covers delivered	No data available per sector		1774
Median time duration for aluminium cover installation	45 min (the full range was from 10 min to 3 hours)		

The monitoring activities involved four meetings with 47 community members (community leaders and intervention beneficiaries) held during April and September 2016 in three neighbourhoods of sector 1 (Portachuelo, Kennedy and Triunfo) and five neighbourhoods of sector 2 (San Jorge, Obrero, Santa Fe, Esmeralda 3 and Santa Isabel). These meetings served as an opportunity to communicate intervention objectives and progress, educate about VBD prevention and control measures and to request information regarding satisfaction and suggestions for ways in which intervention could be improved. In addition, field research staff carried out entomological follow-up and cover installation surveys in targeted premises. Follow-up entomological surveys were carried out between January 1, 2017, and August 11, 2017 in 1580 premises (882 in sector 1 and 698 in sector 2) and cover acceptability surveys began on January 17, 2017, and ended on December 13, 2017 reaching 652 households in sector 1 and 593 in sector 2 (Figure 3.8). School students promoted the intervention, educated in the proper use of the water-holding container covers (students had first been educated in the proper use themselves before helping to promote the intervention), raised awareness by placing posters around neighbourhoods and participated in entomological follow-up surveys.

The MSC was stablished on December 7, 2016, after 11 committee meetings, the last meeting being held in December 2017. During the MSC meetings diverse vector control actions were proposed and carried out per sector involved. Most of the actions proposed by the MSC were delivered during this action phase.

c. Sustainability phase (2017-2018):

This third phase comprised the activities needed to ensure the continuation of the change process triggered by the previous two phases and as a precondition for achieving sustained long-term effects. Since the beginning of the design of the intervention under study, the research team had been preparing for building actions towards sustainability. The intervention was designed and conducted under an Ecohealth approach. (36,37).

One of the main strategies was the implementation of the process of vertically scaling-up the intervention by promoting the development of an MSC. In addition, the research team carried out 3 meetings with the mayor of Girardot for him to take over the responsibility for the continuation of processes, and a closure meeting to which diverse stakeholders of Girardot were invited (July 27, 2018). In this meeting, presided over by the Municipality Mayor, the research team presented and discussed study results.

Intervention theory of "Girardot *Aedes-Free* "

Before presenting the theory of the intervention and its different components specific descriptors (3) of the intervention are presented in Table 3.6.

Table 3.6. Specific descriptors of "Girardot *Aedes-Free*" intervention

Descriptors	Definition
What (procedures, activities, and/or processes used in the intervention)?	Raise awareness and strengthen knowledge on dengue and other *Aedes*-borne diseases through information and communication tools Multisectoral and intersectoral collaboration Environmental management through targeting productive *Ae. aegypti* breeding sites
How (modes of delivery)?	Materials: posters, brochures, flyers, and banners School workshops Institutionalization of a multisectoral and intersectoral action committee Door-door customizing Insecticide treated material lids for productive containers
How often?	During December 4, 2015, to February 24, 2017. 1.5 container lids per household and communication materials delivered
To whom?	Community at different levels: school, neighbourhoods, tourists, householders
Who (Intervention provider)?	Non-profit organization with local institutions representing different sectors
Where (Context)?	Hyperendemic dengue municipality in Colombia

The theory of the intervention revolved around the following four components that interact at different levels and are illustrated in Figure 3.9:

1. Multisectoral action mobilization: different actors were identified and contacted to start a joint action collaboration.
2. Community action: consisted in carrying out activities for and with the community. These activities focused in promoting participation of community leaders, schools, and household members. In addition, environmental management through targeting *Aedes*-productive containers.
3. Operational planning: study set-up, training and designing education and communication tools.
4. Monitoring and evaluation: carried out by the research team consisted in weekly meeting between research team members, field visits to field team members, three visits to households during baseline activities, covers implementation and follow-ups surveys.

The expected proximal (intermediate effects) resulting from the interaction of these components were increased community awareness and knowledge about dengue and other *Aedes*-borne diseases and capacity for action, institutionalization of a multisectoral and intersectoral committee and policy development through multisectoral collaborations, as well as the institutionalization of the intervention in the local health programme. The continuing environmental control of *Ae. aegypti* and sustainability of other vector prevention and control actions was predicted to result in a reduction in vector density and dengue transmission.

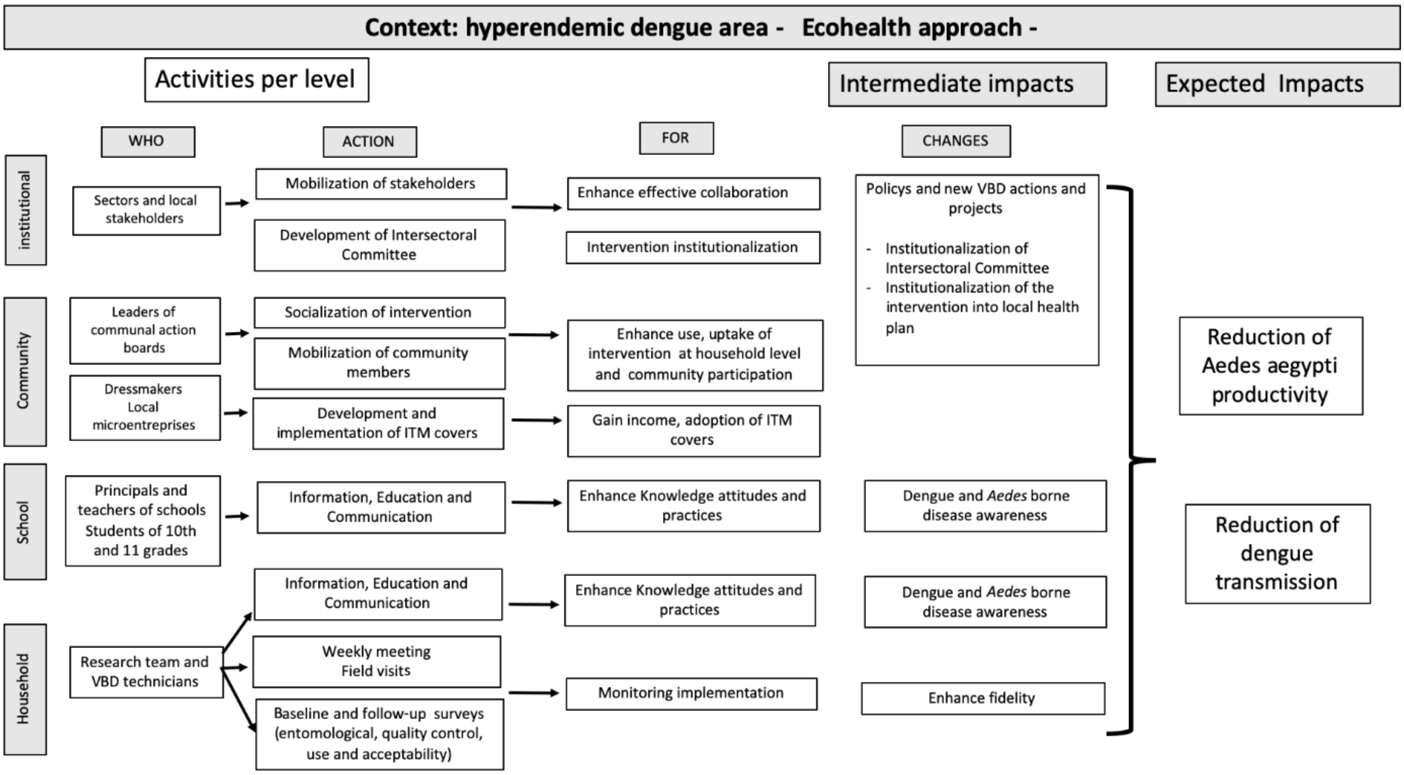


Figure 3.9 Theoretical model for "Girardot Aedes-Free" intervention

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Chapter 4 Study 1. Evaluation of the effectiveness of insecticide-treated container covers as a household environmental management tool for *Aedes aegypti* control

4.1 Outline

This chapter, corresponding to Study 1, assesses the effectiveness of ITCo (as the principal household-level action of "Girardot *Aedes-Free"* intervention) targeting productive breeding sites for reducing *Ae. aegypti* density. This study relates to Research Question 1: What is the effectiveness of a community-centred environmental management intervention in reducing dengue incidence and *Ae. aegytpi* populations in a hyperendemic municipality of Colombia.

4.2 Introduction

Ae. aegypti is anthropophilic and highly adapted to urban environments. It shows a preference to reproduce in a wide range of artificial and natural containers with fresh and clean water. High productivity of immature stages of the vector, is associated with water storage in uncovered large household containers (1–7). *Ae. aegypti* control has become challenging due to urbanisation and environmental conditions such as weak infrastructure, poor sanitation and lack of vector control programme implementation and sustainability (8–12).

Available vector control tools, having varying degrees of efficacy, include the use of biological agents, application of chemical products and environmental management (13). The latter method entails emptying or destroying water containers, cleaning vector breeding sites, using container covers (with or without insecticide-treated materials), applying waste management strategies, implementing community-based clean-up campaigns, and the installation of piped water supply (14).

Among the most recent environmental management strategies related to the control of containers, is the use of insecticide-treated materials (ITM) as covers for the most productive breeding containers. This is a strategy that aims to impact vector populations by treating only water containers that produce the greatest number of pupae with an additional control effect (mechanical barrier for oviposition and adult emergence and insecticidal effect); the strategy also has potential for effective community-level dengue control.

ITMs use synthetic pyrethroids which are one of the group of insecticides currently recommended for the treatment of nets. Deltamethrin and permethrin are the two most common active ingredients, which are used due to their favourable safety profile and biological performance. Deltamethrin is particularly suitable for use in the impregnation of nets since it is effective at very low doses. ITMs also vary in the type of material used in their manufacture. Currently they are manufactured from either polyester or polyethylene. These two types of plastics differ in their attributes, which can influence either the durability of the net or the comfort that is experienced by the user.

The literature regarding ITM for the control of *Ae. aegypti* provides evidence that these materials used as covers for productive breeding containers show promising results in the reduction on *Ae. aegypti* densities and potentially on dengue transmission. For example, a cRCT conducted in Venezuela and Mexico (15) using curtains in combination with container covers showed that, in Mexico, PPI fell from 3.4 at baseline to 0.36 after a year and, in Venezuela, from 3.0 to 0.3, both reductions being significant. The study in Venezuela also reported significant results in DENV seroprevalence data. DENV IgM seroprevalence decreased from 16% at baseline to 8% after the intervention. Quintero et al. (16), in Colombia, reported a significant reduction in Breteau index (from 14 at baseline to 6 post-intervention) after 6 months of intervention (curtains), and a significant reduction in intervention clusters and an increase in control clusters for PPI after the second intervention (covers).

Other studies conducted by Rizzo et al. (17) and Tun-Lin et al. (18) reported variable results. The study conducted by Rizzo et al, in Guatemala concluded that ITM curtains and jar covers substantially reduce almost all entomological indices, except in the case of the container index where no statistically significant differences were observed. Tun-Lin et al.'s study conducted in Venezuela reported no significant differences for PPI reduction after the intervention (PPI intervention group: -6.6%, PPI control group: -13.0%) and a comparable increase in BI for intervention and control group (BI: intervention group: 25.9%, BI control group: 30.3%).

Additionally, ITM are being used for the control of *Ae. aegypti* as window screens or curtains with promising results in the reduction on *Ae. aegypti* densities and on dengue transmission, although results are dependent on protective practice, coverage and the characteristics of the site (16,17, 20–29) (See Appendix Table A-3,). These materials target the adult mosquito, epidemiologically the most important vector stage. ITMs used as door and window screens were tested in Merida, Mexico by Chez-Mendoza et al. in 2015 (23). The study showed a significant difference between intervention and control clusters in all Stegomyia indicators and PPI. Likewise, in 2015, Manrique-Saide et al. (24) conducted a cRCT in Acapulco, evaluating screens. The study reported a decrease in adult infestations after 5 months in intervention clusters that was maintained a year after intervention. On the other hand, a cRCT conducted in Thailand that evaluated only the use of curtains did not find significant differences in entomological indexes between intervention and control clusters (27). In Peru, a study conducted by Lenhart et al. (20) showed that there were no statistically significant differences between ITM and non-ITM clusters among entomological indicators and DENV seroconversion data showed that individuals within intervention clusters were at greater risk of seroconverting to dengue virus (seroconversion rate of 50.6 per 100 person-years (CI: 29.9–71.9), compared to individuals in the control arm that had an average seroconversion rate of 37.4 per 100 person-years (CI: 15.2–51.7).

This study aimed to investigate the effectiveness of household-level action where insecticide treated water container covers were designed and distributed to *Ae. aegypti* productive containers through community actions as part of *Girardot Aedes-Free* intervention.

4.3 Methods

4.3.1 Intervention components and context

As described in Chapter 3, household-level actions of "Girardot *Aedes-Free"* intervention consisted in the distribution of ITCo for the most productive *Ae. aegypti* breeding sites (Figure 4.1). In the study area, *Ae.* a*egypti* productivity is strongly associated with the storage of water in uncovered cement containers known as "albercas". This type of container accounts for more than 70% of pupae production (1).

Figure 4.1. Productive A*e. aegypti* breeding sites ("albercas") covered with insecticide treated materials

5708 ITCo were distributed between December 4th, 2015, and April 10th, 2017, in study Sectors 1 and 2. At the time of ITCs deployment, the epidemiological surveillance system of Girardot reported 384 cases of dengue and severe dengue. In addition, in October 2015, the Zika virus had spread through Girardot and between the 15th of December 2015 and January 15th 2016 the highest number of cases were reported (29,30). In response to this emergency, local government vector control activities occurred all over the municipality with a breeding-site reduction campaign, larviciding with temephos, and implementation of a community mobilisation strategy called "Familias que transmiten vida" (31).

4.3.2 Study design

A secondary data analyses was considered for the evaluation of the effectiveness of ITCo (one of the various components of "Girardot *Aedes-Free"* intervention) in reducing *Ae. aegypti* entomological indices and the evaluation of the acceptability of ITCo by household members. For analysis the following data from the datasets of the project "*Ecobiosocial approach for the design and implementation of a sustainable strategy for dengue vector control in Colombia"* were used.

a. Acceptability database: this dataset includes information collected by a survey (Appendix D1) administered to 1163 household members that received ITC, between January 17th, and December 13th, 2017. The information includes conditions of container covers, peoples' perceptions and satisfaction, use of covers, and use of other vector control tools.

b. Household and public space database*:* this dataset contains information from cross-sectional surveys conducted in households (Appendix D2) and public premises (Appendix D3) from intervention and control areas both, before and after implementation. Baseline surveys were conducted between July 7th, 2015, and January 31st, 2017, and endline surveys between January 31st, 2017, and August 12th, 2017, (12-18 months post-intervention) by trained field staff. The surveys assessed information regarding the ITCo installed, types of containers, characteristics of containers, presence of immature vector forms, and number of pupae as well as information regarding household and public premises characteristics as well as other vector control practices.

Baseline entomological surveys were conducted in 2669 premises (1350in Sector 1 and 1319 in Sector 2). 56.1% (n=1497) of pre-intervention households (2669 premises at baseline) were inspected during post-intervention surveys (Figure 4.2).

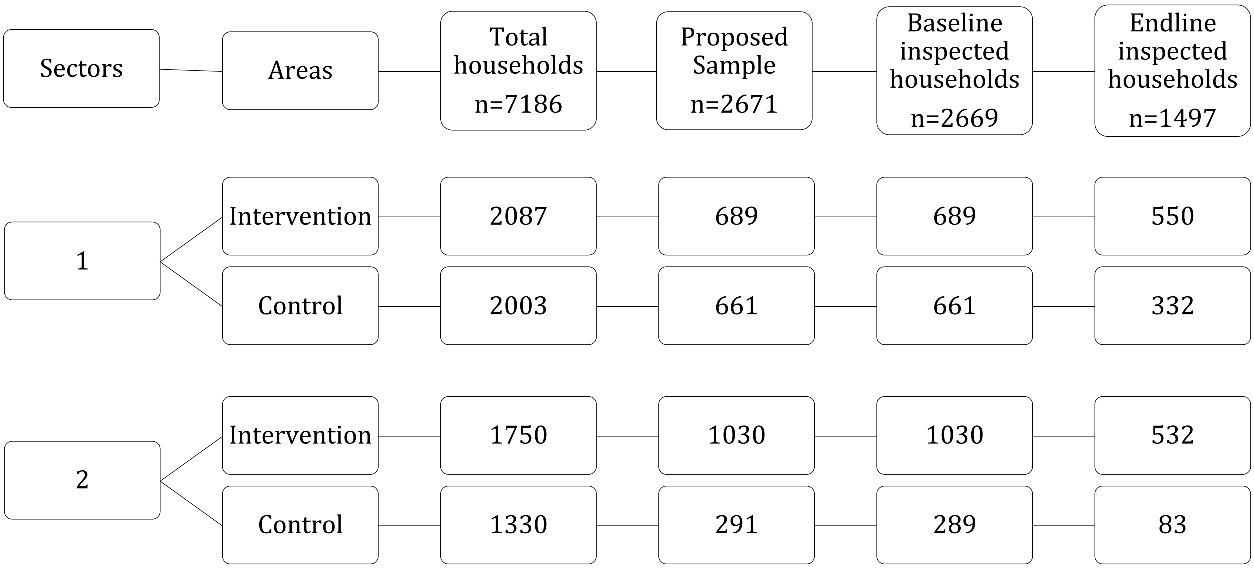

Figure 4.2. Number of pre-intervention and post-intervention entomological household surveys

4.3.3 Data management and analysis

The dataset available in a spreadsheet in CVS format was cleaned using Excel and Stata/SE 16 software (StataCorp, College Station, TX, USA). 5 % of paper baseline surveys (n=75) and follow-up surveys (n=133) were reviewed by checking validity of entered values to the Excel data sets. Cleaned Excel data sets were transferred to Stata for exploratory and statistical analysis.

a. Acceptability data: a descriptive analysis was conducted presenting data as frequencies and percentages. Acceptability was understood in terms of the perceptions among household members about cover satisfaction, use, perceived effectiveness, willingness to purchase and willingness to recommend to others.

b. Household and public space data: a descriptive analysis of baseline and endline characteristics was performed for each study group (intervention and control), per sector (Sector 1 and Sector 2) and time of evaluation (before and after intervention). Different entomological indicators were calculated for households and public spaces (Table 4.1). In addition, pupal productivity was calculated for different container types, as the total number of pupae in the container type, divided by the total number of pupae in all containers, multiplied by 100.

Table 4.1. Entomological outcomes

Outcome	Definition
Positive containers for larvae + pupae	Number of accessible containers with larvae and pupae
Positive containers for pupae	Number of accessible containers with pupae
Positive households for larvae + pupae	Number of households with larvae and pupae
Positive households for pupae	Number of households with pupae
House larvae + pupae index (HI)	Number of households with *Ae. aegypti* immatures / total number of inspected households per 100 inspected households
House pupa index (HIp)	Number of households with pupae / total number of inspected households per 100 inspected households
Container larvae + pupae index (CI)	Number of containers with *Ae. aegypti* immatures / total number of inspected containers per 100 inspected containers
Container pupae index (CIp)	Number of containers with *Ae. aegypti* pupae / total number of inspected containers per 100 inspected containers
Breteau larvae + pupae index (BI)	Number of containers positive for *Ae. aegypti* immatures/houses inspected) ×100
Breteau pupae index (BIp)	Number of containers positive for *Ae. aegypti* pupae/houses inspected) ×100
Pupae per person (PPI)	Number of pupae collected/persons living in each sector and area were computed at the sector level.

Relative and absolute frequencies were calculated, as well as central trend and dispersion measures. The impact of treatment on each entomological metric was analysed initially by evaluating the difference between control and treatment areas across the sector and survey dates with Fisher or Chi-squared test (for qualitative data), or t-Student or Mann Whitney tests (for quantitative data), according their distribution. In addition, the difference-in-differences (DID) and difference-of-endpoints (DOE) were calculated. The first was calculated comparing the differences before and after the intervention between the intervention and the control group, and the second comparing the endpoint measures between the intervention and the control group. Both effect measures (DID and DOE) were calculated for BI and PPI in each study sector using measures at baseline (b) and endpoint (e) separated by intervention (I) and control (C) group according to the following formulas: DID BI= $(BI_{eI}-BI_{bI})-(BI_{eC}-BI_{bC})$, DID PPI = $(PPI_{eI}-PPI_{bI})-(PPI_{eC}-PPI_{bC})$, DOE BI = $BI_{eI}-BI_{eC}$ and DOE PPI = $PPI_{eI}-PPI_{eC}$

Furthermore, bivariate, and multivariate exploratory analyses were used to estimate the impact of interventions in the presence of larvae and pupae of *Ae. aegypti,* adjusted by possible confounding factors and covariables (sector, season, container water capacity, localisation of container, top coverage of container and household income) according to the contextual relevance of these factors in both households and public spaces. These analyses were based on a robust logistic regression. Model assumptions were validated through a linearity test, the Hosmer-Lemeshow test, estimation of deviance residuals and leverage values, and comparison made between the crude and the adjusted models. Hypothesis testing to determine the level of statistical significance was carried out using a 95% confidence interval and a P value less than 0.05 ($P<0.05$).

4.4 Results

4.4.1 Acceptability

Overall acceptability of the covers was high when analysing the percentages of covers in use (84.09%) and the overall satisfaction of covers delivery reported (92.09%). Thirteen percent (n=159) of covers were not being used at the time of the survey. The majority of household members rated as good the quality of cover materials (82.29%). Few household members (3%, n=37) reported that covers need repaired regarding aluminium frames and ITM fragility (n=121, 76%) (Table 4.2).

Table 4.2. Proxy variables of acceptability of insecticide treated covers

Householders responses	**N**	**%**
Type of covers installed		
Aluminium covers	1194	99.67
Round covers	4	0.33
Total	1198	100%
Covers installed currently in use		
Yes	1004	84.09
No	159	13.32
Covers repaired		
Yes	37	3.10
No	1150	98.88
Materials repaired		
Net (mesh) repaired	21	56.76
Aluminium frames repaired	16	43.24
Reasons for not using the covers		
Damage of covers	121	76.10
Elimination of water-holding container	20	12.58
Other	18	11.32
Time elapsed from installation to cover repair	3 days to 3 months	
Cover easy to use		
Yes	1041	89.51
No	78	6.71
NR*	44	3.78
Water-holding container easy to clean		
Yes	1055	90.71
No	68	5.85
NR*	40	3.44
Satisfaction of covers delivery		
Yes	1071	92.09
No	92	7.91
Quality of covers materials		
Good	957	82.29
Fair	126	10.83

Poor	66	5.67
NR*	14	1.20
Recommend changes to covers		
Yes	279	23.99
No	884	76.01
Perceived presence of less mosquitoes, larvae o pupae in tanks		
Yes	729	62.68
No	410	35.25
NR*	24	2.06
Decrease in purchase of insecticide/larvicides decreased since cover installation		
Yes	92	7.91
No	1054	90.63
NR*	17	1.46
Willingness to recommend covers to others		
Yes	1085	93.29
No	61	5.25
NR*	17	1.46
Willingness to pay for covers		
Yes	1012	87.02
No	133	11.44
NR*	18	1.55

NR*: no response

4.4.2 Description of Aedes aegypti indices

This section initially presents the descriptive analysis on *Ae. aegypti* breeding sites inspected in both households and public areas before and after the intervention, followed by entomological indicators from both households and public places before and after the intervention and container productivity. Furthermore, the results of two statistical models are provided, one for household data and the other for public places, both of which analyses the impact of the intervention in the presence *of Ae. aegypti* larvae and pupae.

a. *Household Ae. aegypti* breeding-sites and indices

A total of 3886 containers holding water in households of sector 1 were identified during pre-intervention surveys (July 7th, 2015 – February 10th, 2016, in Sector 1) and 3025 in sector 2 (September 14th, 2016 until January 30th,2017) (Table 4.3). Among the 6911 identified containers, 82% (n=5639) were accessible (Figure 4.3). In both sectors, entomological indexes were higher in control areas compared to intervention areas. Sector 1 compared to Sector 2 reported higher indexes in both intervention and control areas (Table 4.3).

Water tank type 1 | Water tank type 2 | Bucket | Metallic Bucket

Figure 4.3. Type of *Ae. aegypti* productive containers

At endline (January 31st, 2017, and August 10, 2017), 2345 containers in households of sector 1 were identified and 1438 in Sector 2. 81% (n= 3056) of containers identified were accessible. In both sectors, entomological indexes were higher in control areas compared to intervention areas, although sector 1 reported higher indexes (Table 4.4).

Table 4.3. Pre-intervention entomological indices of inspected households in sectors 1 and 2, per intervention and control areas

Characteristics and entomological indices	Sector 1					Sector 2				
	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected households	689	51.04	661	48.96	1350	1030	78.09	289	21.91	1319
Persons	2701	51.68	2525	48.32	5226	3637	77.93	1030	22.07	4667
Total of containers	1899	48.87	1987	51.13	3886	2289	75.67	736	24.33	3025
Containers accessible for inspection	1558	47.85	1698	52.15	3256	1819	76.33	564	23.67	2383
Positive containers for larvae +pupae	190	45.35	229	54.65	419	199	73.70	71	26.30	270
Positive containers for pupae	51	41.46	72	58.54	123	35	63.64	20	36.36	55
Positive households for larvae + pupae	168	46.93	190	53.07	358	165	72.05	64	27.95	229
Positive households for pupae	49	42.61	66	57.39	115	31	62.00	19	38.00	50
Estimated pupas	830	40.69	1210	59.31	2040	1085	70.50	454	29.50	1539
House larvae + pupae index	24%		29%			16%		22%		
House pupa index	7%		10%			3%		7%		
Container larvae + pupae index	12%		13%			11%		13%		
Container pupae index	3%		4%			2%		4%		
Breteau larvae + pupae index	28		35			19		25		
Breteau pupae index	7		10			3		7		
Pupae per person index	0.31		0.48			0.30		0.44		

Table 4.4. Post-intervention entomological indices of inspected households in sectors 1 and 2, per intervention and control areas

Characteristics and entomological indices	Sector 1					Sector 2				
	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected households	550	78.12	332	37.64	882	532	86.50	83	13.50	615
Persons	2065	80.53	1289	38.43	3354	1998	85.17	348	14.83	2346
Total of containers	1455	62.05	890	37.95	2345	1253	87.13	185	12.87	1438
Containers accessible for inspection	1178	61.77	729	38.23	1907	1002	87.21	147	12.79	1149
Positive containers for larvae + pupae	107	53.77	92	46.23	199	52	71.23	22	28.77	73
Positive containers for pupae	39	52.70	35	47.30	74	16	80.00	4	20.00	20
Positive households for larvae + pupae	95	54.29	80	45.71	175	51	70.83	4	29.17	72
Positive households for pupae	32	48.48	34	51.52	66	16	80.00	4	20.00	20
Estimated pupae	860	47.88	935	52.06	1796	223	80.80	53	19.20	276
House larvae + pupae index	17%		24%			10%		25%		
House pupa index	6%		10%			3%		5%		
Container larvae + pupae index	9%		13%			5%		14%		
Container pupae index	3%		5%			2%		3%		
Breteau larvae + pupae index	19		28			10		25		
Breteau pupae index	7		11			3		5		
Pupae per person index	0.42		0.73			0.11		0.15		

When analysing baseline entomological information according to seasons (dry and rainy) for sector 1, there are slightly more containers during the dry season compared to the rainy season in both intervention and control areas. In the dry season (July-September and January), a total of 2097 containers were found in 841 households, accounting for 2.5 containers per house and, in the rainy season (Oct-Dec), 1159 containers were found in 500 inspected households, an average of 2.3 containers per house. In sector 2, no differences were found between dry and rainy seasons; in both there were 1.8 containers per households. Entomological indices were similar between seasons except for PPI which is higher during the dry season (0.45 vs 0.27) (Appendix D4, Table D4-1 and Table D4-2).

Endline surveys produced similar results. In both sectors, there were more containers accessible for inspection during the dry season (1433) compared to the rainy season (912), in both intervention and control areas. Entomological indices (all immature forms) were higher in the dry season than in the rainy season (Appendix D4, Table D4-3 and Table D4-4).

b. Public premises *Ae. aegypti* breeding sites and indices

During the same study period, 1530 public spaces were inspected, and 1834 containers were found during baseline surveys — of these, 82% (n=1503) were accessible for inspection. During post-intervention surveys, 1517 public spaces were inspected, and 1845 containers found, of which 85.36% were accessible for inspection (Tables 4.5 and 4.6, Figure 4.4). All entomological immature indices were higher than household indices, especially in sector 1 (Table 4.5). During endline surveys, *Ae. aegypti* indices decreased in both sectors and in both intervention and control areas (Table 4.6).

Figure 4.4. Type of *Ae. aegypti* productive containers in public spaces

Table 4.5. Pre-intervention inspected public spaces in sectors 1 and 2, per intervention and control areas

Characteristics and entomological indices	Sector 1					Sector 2				
	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	362	49.52	369	50.48	731	593	74.22	206	25.78	799
Total of containers	434	51.91	402	48.09	836	765	76.65	233	23.35	998
Containers accessible for inspection	352	52.69	316	47.31	668	638	76.41	197	23.59	835
Positive containers for larvae + pupae	96	50.79	93	49.21	189	170	89.47	20	10.53	190
Positive containers for pupae	44	48.89	46	51.11	90	68	89.47	8	10.53	76
Positive public space for larvae + pupae	82	50.93	79	49.07	161	109	85.83	18	14.17	127
Positive public space for pupae	42	49.41	43	50.59	85	49	85.96	8	14.04	57
Estimated pupas	325	49.54	331	50.46	656	458	81.49	104	18.51	562
Public space larvae + pupae index	23%		21%			18%		9%		
Public pupa index	12%		12%			8%		4%		
Container larvae + pupae index	27%		29%			27%		10%		
Container pupae index	13%		15%			11%		4%		
Breteau larvae + pupae index	27		25			29		10		
Breteau pupae index	12		12			11		4		

Table 4.6. Post-intervention entomological indices of inspected public spaces in sectors 1 and 2, per intervention and control areas

Characteristics and entomological indices	Sector 1					Sector 2				
	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	327	50.08	326	49.92	653	634	73.38	230	26.62	864
Total of containers	366	51.62	343	48.38	709	858	75.53	278	24.47	1136
Containers accessible for inspection	288	50.70	280	49.30	568	728	79.13	240	20.87	968
Positive containers for larvae + pupae	81	45.51	98	55.06	178	114	83.82	22	16.18	136
Positive containers for pupae	25	47.17	28	52.83	53	40	90.91	4	9.09	44
Positive Public space for larvae + pupae	66	45.21	80	54.79	146	89	81.65	20	18.35	109
Positive Public space for pupae	23	47.92	25	52.08	48	33	89.19	4	10.81	37
Estimated pupas	232	39.12	361	60.88	593	523	98.31	9	1.69	532
Public space larvae + pupae index	20%		25%			14%		9%		
Public pupa index	7%		8%			5%		2%		
Container larvae + pupae index	25%		35%			16%		9%		
Container pupae index	8%		10%			5%		2%		
Breteau larvae + pupae index	25		30			18		10		
Breteau pupae index	8		9			6		2		

When analysing baseline entomological information according to seasons (dry and rainy) there were slightly more containers per inspected premises during the rainy season (0.99) compared to dry season (0.85), in both intervention and control areas. In the dry season (January to February and July to September) a total of 359 containers were found in 420 public premises and in the rainy season (March to May and October to December), 309 containers were found in the 311 inspected premises. In sector 2, more containers were identified than in sector 1, but there were more containers per inspected public space during the dry (2.9) compared to the rainy season (1.0) (Appendix D5, Table D5-1 and Table D5-2). Endline surveys evidenced similar results. In both sectors, there were more containers accessible for inspection during the rainy season (836) compared to the dry season (905), in both intervention and control areas. Entomological indices were higher in rainy seasons in both sectors (Appendix D5, Table D5-3 and Table D5-4).

c. Household *Ae. aegypti* productive breeding-sites

The type of household water-holding containers found during baseline inspection are shown in Table 4.7. The presence of *Ae. aegypti* pupae was reported in 6 different types of containers in the intervention area and in 8 different types of containers in the control area. The most productive container in both sectors (intervention and control areas) was water tank type 1 (concrete washbasins for laundry (albercas) (Figure 4.5), which accounted for more than 90% of pupae counted (Table 4.7) (Sector 1: intervention area 83% and control area 78%; sector 2: intervention area 92% and control area 76%; Appendix D6, Table D6-1 and Table D6-2); followed by water tank type 2 and ground plastic containers. Mean pupae per water tanks type 1, water tanks type 2 and ground plastic containers were lower in intervention areas (1.01) than in control areas (1.56).

Water tank type 1

Water tank type 2

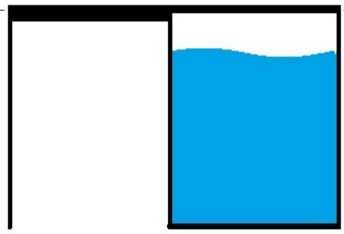

Figure 4.5. Types of water tanks (concrete washbasins)

Table 4.7. Baseline frequency of water-holding containers and pupal productivity in households, per intervention (I) and control (C) areas

Type of containers	Containers				Containers with pupae				Pupal productivity				Container Index*	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	156	4.62	174	7.69	5	5.81	5	5.21	83	4.33	125	7.54	3.21	2.87
Elevated tank (plastic)	11	0.33	3	0.13	0	0	0	0	0	0	0	0	0	0
Water tank type 1	1491	44.15	708	31.30	63	73.26	67	69.79	1684	87.94	1291	77.64	4.23	9.46
Water tank type 2	219	6.49	119	5.26	9	10.47	6	6.25	127	6.63	172	10.32	4.11	5.04
Jar, vessels	689	20.40	401	17.73	2	2.33	3	3.13	5	0.26	38	2.29	0.29	0.75
Buckets	552	16.35	552	24.40	3	3.49	11	11.46	9	0.47	25	1.50	0.54	1.98
Flower vases pots	101	2.99	83	3.67	4	4.65	1	1.04	7	0.37	2	0.12	3.96	1.20
Used tyres	7	0.21	7	0.31	0	0	0	0	0	0	0	0	0	0
Rainwater drain	1	0.03	0	0.00	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	111	3.29	171	7.56	0	0	2	2.08	0	0	6	0.36	0	1.17
Natural	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
Other	39	1.15	44	1.95	0	0	1	1.04	0	0	4	0.24	0	2.27
Total (n)	3377	100	2262	100	86	100	96	100	1915	100	1663	100	2.55	4.24

*Number of containers with any larvae or pupae, divided by the total number of containers in that category × 100

Table 4.8 describes the pupae productivity after the intervention was implemented. When compared with baseline surveys, pupae productivity is similar. In both sectors, water tank type 1 produced the majority of the pupae (Sector 1: intervention area 68% and control area 88%; Sector 2: intervention area 82% control area 70%; Appendix D6, Table D6-3 and Table D6-4). The second most productive containers were water tanks type 2 — these produced 16% of pupae in intervention areas and 10% in control areas, followed by ground plastic containers that accounted for 12% of pupae in the intervention area and 5% in the control area.

Table 4.8. Endline frequency of water-holding containers and pupal productivity in households stratified by intervention (I) and control (C) areas.

Type of containers	Containers				Containers with pupae				Pupal productivity				Container Index*	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	78	3.58	45	5.14	4	6.78	3	8.33	131	12.10	49	4.95	5.12	6.67
Elevated tank (plastic)	3	0.14	1	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1	962	44.13	330	37.67	40	67.8	30	83.33	766	70.73	871	88.07	4.16	9.09
Water tank type 2	140	6.42	50	5.71	8	13.5	2	5.56	940	16.07	939	6.88	5.71	4
Jar, vessels	559	25.64	232	26.48	3	5.08	1	2.78	2	0.18	1	0.10	0.54	0.43
Buckets	333	15.28	179	20.43	3	5.08	0	0	9	0.83	0	0	0.90	0
Flower vases pots	33	1.51	15	1.71	0	0	0	0	0	0	0	0	0	0
Used tyres	2	0	3	0	1	1.69	0	0	1	0.09	0	0	50	0
Rainwater drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	46	2.11	10	1	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	24	1.10	11	1.26	0	0	0	0	0	0	0	0	0	0
Total (n)	2180	100	876	100	59	100	36	100	1083	100	989	100	2.71	4.11

* Number of containers with any larvae or pupae, divided by the total number of containers in that category × 100

The mean number of pupae per container decreased in intervention (from 1.05 to 0.84) and increased control areas (from 1.76 to 2.47), for both type 1 and 2 water tanks — however, it was higher in control areas. For ground containers, the mean pupae per container in intervention areas was higher compared to control areas (1.67 vs 1.08 pupae per container). When comparing baseline and endline surveys, the intervention area reported a decrease in the mean pupae per all containers (from 0.57 to 0.50) while control areas reported an increase in the mean pupae per container (from 0.74 to 1.12). Similarly, the mean pupae per water tank type 1 decreased from 1.13 to 0.79 in intervention areas and increased in control areas from 1.82 to 2.63. A different situation occurred with ground containers where there was an increase in the mean pupae from 0.53 to 1.63 in intervention areas (Table 4.8).

d. Public spaces *Ae. aegypti* productive breeding sites

Table 4.9 presents pupal productivity by type of container found in inspected public spaces pre-intervention. Rainwater drains were the most productive containers, accounting for 91% of pupae in intervention areas and 95% of pupae in control areas. Per sector, the most productive containers in public spaces at baseline, in intervention as well as in control areas, were rainwater drains, with 633 pupae in Sector 1 and 491 pupae in Sector 2. In Sector 2, tires and vessels were the second most productive containers containing 70 pupae (15%) (Appendix D7, Table D7-1 and Table D7-2).

Table 4.9. Pre-intervention frequency of water-holding containers and pupal productivity in public spaces stratified by intervention (I) and control (C) areas.

Types of containers	Containers				Pupal productivity				Containers with pupae				Container Index*	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	5	0.51	5	0.97	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1	1	0.10	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jar, vessels	34	3.43	26	5.07	30	3.83	0	0	2	1.77	0	0	5.88	0
Buckets	32	3.23	5	0.97	1	0.13	0	0	1	0.88	0	0	3.13	0
Flower vases pots	1	0.10	0	0	1	0.13	0	0	1	0.88	0	0	100	0
Used tires	26	2.63	4	0.78	40	5.10	0	0	1	0.88	0	0	3.85	0
Rainwater drains	777	78.48	402	78.36	712	90.82	412	94.71	108	95.58	53	98.15	13.90	13.18
Cans, bottles, unusable (trash)	103	10.40	65	12.67	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	11	1.11	6	1.17	0	0	23	5.29	0	0	1	1.85	0	16.67
Total (n)	990	100	513	100	784	0	435	100	113	100	54	100	11.4	10.53

Table 4.10 presents endline pupal productivity per type of container found in inspected public spaces. Rainwater drains were still the most productive containers, accounting for 93% of pupae in intervention areas and 89% in control areas. In control areas, the second most productive containers were cans and bottles, accounting for 11% of pupae (Appendix D7, Table D7-3 and Table D7-4).

Table 4.10. Post-intervention frequency of water-holding containers and pupal productivity in public spaces stratified by intervention (I) and control (C) areas

Types of containers	Containers				Pupal productivity				Containers with pupae				Container Index*	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	0	0	3	0.58	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1	2	0.19	0	0	21	2.78	0	0	1	1.54	0	50	0	50
Water tank type 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jar, vessels	21	1.99	12	1.14	0	0	0	0	0	0	0	0	0	0
Buckets	8	0.76	3	0.28	18	2.38	3	0.81	1	1.54	1	12.5	33.33	12.5
Flower vases pots	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
Used tires	43	4.08	10	0.95	10	1.32	0	0	1	1.54	0	2.33	0	2.33
Rainwater drain	796	75.45	391	37.06	705	93.38	328	88.65	61	93.85	28	7.66	7.16	7.66
Cans, bottles, unusable (trash)	184	17.44	101	9.57	1	0.13	39	10.54	1	1.54	3	0.54	2.97	0.54
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	1	0.09	0	0	0	0	0	0	0	0	0	0	0	0
Total (n)	1055	100	520	100	755	100	370	0	65	100	32	6.16	6.15	6.16

4.4.3 Effectiveness of the intervention

a. Impact on household immature *Ae. aegypti* indices

When comparing entomological indices, immature (larvae and pupae) indices decreased overall after intervention implementation in both intervention and control areas but decreased further in intervention areas, with significant differences — except for container index and PPI that increased in control areas. The container index decreased in intervention areas after the intervention (from 12% to 6%) and this decrease was significant (diff – 0.06, 95% CI [- 0.08, -0.0.04]) but increased slightly in control areas after intervention (from 13% to 15%), although the differences were not significant (diff 0.02 95% CI [-0.02, 0.06]). Breteau Index (BI) decreased from 22.6 to 11.7 in intervention areas (diff 0.11, 95% CI [0.08, 0.14]) and from 31.6 to 27 in control areas (diff 0.05, 95% CI [0.00, 0.10]). DID BI value resulted in a positive result of -6. The difference post intervention (DOE BI) between intervention and control areas was -0.15 and was significant (95% CI: -0.19, - 0.10). Compared to DID BI, differences in the PPI showed opposite results with a negative effect (+ 0.18), whereas DOE PPI resulted in a positive effect (-0.35) (Table 4.11) (Appendix D8, Table D8-1 and Table D8-2).

Table 4.11. Baseline and endline entomological outcomes of inspected households per intervention (I) and control (C) areas

Characteristics and entomological indices	Pre-intervention					Post-intervention				
	I		C		Total	I		C		Total
	n	%	n	%		n	%	n	%	
Inspected households	1719	64.40	950	35.59	2669	1165	73.73	415	26.27	1580
Persons	6338	64.06	3555	35.93	9893	4411	72.93	1637	27.07	6048
Total of containers	4188	60.60	2723	39.40	6911	2893	72.91	1075	27.09	3968
Containers accessible for inspection	3377	59.89	2262	40.11	5639	2327	72.65	876	27.35	3203
Positive containers for larvae + pupae	389	56.46	300	43.54	689	181	61.36	114	38.64	295
Positive containers for pupae	86	48.31	92	51.69	178	59	60.20	39	39.80	98
Positive households for larvae + pupae	333	56.73	254	43.27	587	167	62.31	101	37.69	268
Positive households for pupae	80	48.48	85	51.52	165	52	57.78	38	42.22	90
Estimated pupas	1915	53.51	1664	46.49	3579	1137	53.48	989	46.52	2126
House larvae + pupae index	19%		27%			12%		25%		
House pupa index	5%		9%			3%		5%		
Container larvae+ pupae index	12%		13%			6%		15%		
Container pupae index	3%		4%			2%		3%		
Breteau larvae + pupae index	23		32			12		27		
Breteau pupae index	4.70		8.90			3		5		
Pupae per person index	0.30		0.47			0.25		0.60		

The logistic regression model run to assess the impact of the intervention in the presence and absence of immature forms of *Ae. aegypti* in households adjusted by different covariables suggests that it was effective in reducing the presence of immature forms (larvae and or pupae) (Table 4.12). The odds ratio (OR) for post-intervention time is 0.71 with a 95% confidence interval of [0.50, 0.99]. This suggests that those household's post-intervention are 0.71 less likely to have immature forms of dengue vector than those before intervention, although borderline it is significant. In addition, households located in intervention areas compared to control areas (OR:0.57, 95% CI [0.44,0.73]), in Sector 2 (OR:0.73, 95% CI [0.57,0.92]), having water tanks totally covered (OR:0.58 95% CI [0.42, 0.79]) and inspected during the rainy season (OR:0.69, 95% CI [0.55, 0.87]), were less likely to present immature forms of dengue vector.

Table 4.12. Logistic regression model of risk factors of presence of *Ae. aegypti* immature forms in households*

Covariate	Odds Ratio	95% CI**	*p* value
Time			
Pre-intervention	Ref	Ref	Ref
Post-intervention	0.71	0.50-0.99	<0.05
Area			
Control	Ref	Ref	Ref
Intervention	0.57	0.44-0.73	<0.001
Time x Area	Ref	Ref	Ref
Post-intervention x Intervention	0.79	0.50-1.26	0.326
Sector			
Sector 1	Ref	Ref	Ref
Sector 2	0.73	0.57-0.92	0.010
Season			
Dry	Ref	Ref	Ref
Rainy	0.69	0.55-0.87	0.001
Days of last tank washing	1.00	1.00-1.01	0.019
Container capacity			
> 20 L	Ref	Ref	Ref
≤ 20 L	0.06	0.02- 0.14	<0.001
Water tank placed under roof			
No	Ref	Ref	Ref
Partially	0.91	0.57-1.43	0.672
Totally	0.58	0.42-0.79	0.001
Container localisation			
Indoor	Ref	Ref	Ref
Outdoor	1.09	0.82-1.45	0.534

Container covered			
No	Ref	Ref	Ref
Partially	1.25	0.79-1.99	0.333
Totally	0.29	0.16-0.53	<0.001
Household income*			
<1 minimum wage	Ref	Ref	Ref
1-2 minimum wage	1.85	1.28-2.69	0.001
3-4 minimum wage	0.95	0.53-1.71	0.869

* 4454 observations made, and 3569 observations used in the logistic regression analysis. ** CI: confidence interval
***minimum wage: US$276

b. Impact on public space immature *Ae. aegypti* indices

When assessing the impact on entomological indices in public spaces, immature (larvae and pupae) indices decreased overall after intervention implementation in both intervention and control areas but decreased further in intervention areas. For example, BI decreased from 27.85 to 20.29 in intervention areas (diff 0.15, 95%CI [0.09, 0.21]) compared to control areas where the BI increased from 19.65 to 21.58 (diff -0.01, 95% CI [-0.08, 0.06]). The DID BI reported a positive result of -6 as well as DOE BI that resulted in a positive result of -2. Immature-based entomological indicators pre and post intervention are summarised in Table 4.13 and DID and DOE in Supplementary information, S5 Table 19 and Table 29.

Table 4.13. Baseline and endline entomological indicators of inspected public spaces per intervention (I) and control (C) areas

Characteristics and entomological indices	Preintervention					Post-intervention				
	I		C		Total	I		C		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	955	62.42	575	37.58	1530	961	63.35	556	36.65	1517
Total of containers	1199	65.38	635	34.62	1834	1224	66.34	621	33.66	1845
Containers accessible for inspection	990	65.87	513	34.13	1503	1055	68.88	520	33.02	1575
Positive containers for larvae +pupae	266	70.18	113	29.82	379	195	61.90	120	38.10	315
Positive containers for pupae	112	67.47	54	32.53	166	65	67.01	32	32.99	97
Positive Public space for larvae + pupae	191	66.32	97	33.68	288	155	60.78	100	39.22	255
Positive Public space for pupae	91	64.08	51	35.92	142	56	65.88	29	34.12	85
Estimated pupas	783	64.29	435	35.71	1218	755	67.11	370	32.89	1125
Public space larvae + pupae index	20%		17%			16%		18%		
Public pupa index	10%		9%			6%		5%		
Container larvae + pupae index	27%		22%			18%		23%		
Container pupae index	11%		11%			6%		6%		
Breteau larvae + pupae index	28		20			20		22		
Breteau pupae index	12		9			7		6		

The logistic regression model ran to evaluate the impact of the intervention in the presence and absence of immature forms of *Ae. aegypti* in public spaces evidenced that, after the intervention was implemented, there was less likelihood of finding immature forms of *Ae. aegypti* in intervention areas, although the reduction was not significant (OR 0.69, 95% CI [0.39,1.20]) — likewise, when considering Sector 2 (OR 0.63, 95% CI [0.31, 1.28]) (Table 4.14).

Table 4.14. Logistic regression model of risk factors of presence of *Ae. aegypti* immature forms in public spaces*

Covariate	Odds Ratio	95% CI**	P value
Time			
Pre-intervention	Ref	Ref	Ref
Post-intervention	1.07	0.71-1.61	0.730
Area			
Control	Ref	Ref	Ref
Intervention	0.87	0.59-1.32	0.558
Time x Area	Ref	Ref	Ref
Post-intervention x Intervention	0.69	0.39 -1.20	0.192
Sector			
Sector 1	Ref	Ref	Ref
Sector 2	0.22	0.12 -0.39	<0.001
Time x sector			
Post-intervention Sector 2	1.59	0.91- 2.77	0.106
Area x sector			
Intervention x Sector 2	3.53	1.79 - 6.95	<0.001
Time x area x sector			
Post-intervention x intervention Sector 2	0.63	0.31-1.28	0.199

* 3329 observations made, and 2106 observations used in the logistic regression analysis. ** CI: Confidence Interval

4.5 Discussion

The findings of this study demonstrated that using ITM as lids for productive water-holding containers reduces entomological immature indices by almost 50% (BI 22.6 to 11.7, CI 12% to 6%,). Furthermore, regression model evidenced that there is less likelihood of finding immature forms in household of intervention areas than control areas.

According to transmission thresholds (32-37), CI and BI are at high risk thresholds (>4% for HI, >3%, >5 for BI) expect for PPI that is below the transmission thresholds (> 0.35 for PPI).) Although these thresholds should be analysed with caution as several factors (environmental, human population characteristics for example: herd immunity, human migration, and cultural practices) influence the threshold values for each vector indices making critical thresholds for larval indices for dengue epidemic management difficult to establish.

Environmental management has been a vector control intervention measure employed for over a decade (38). A recent systematic literature review (SLR) and metanalysis (14) demonstrated that these control measures have weak efficacy in reducing larval and pupal densities of *Ae.* aegypti mosquitoes. Particularly, container covers with and without insecticides were identified and evaluated by the later SLR, evidencing 10 studies (4 studies implemented lids with insecticides and 6 studies without insecticides). The studies that implemented lids with insecticides were all conducted in Latin America under cluster randomised control trials between 2006 and 2015 (16,17,21,39). The studies conducted in Venezuela, Colombia and Guatemala by Kroeger et al. in 2006 (21), Quintero et al. in 2015 (16) and Rizzo et al. in 2012 (17) showed reductions in almost all entomological indices (specially for PPI and BI) in intervention clusters. The study conducted in Venezuela and reported by Tun-lin et al. in 2009 (39) did not show differences in PPI,s but reported an increase in BI in both intervention and control groups.

The studies that implemented lids without insecticides were carried out in Latin-America and the Caribbean (Colombia, Brazil, Uruguay and Cuba), India (Chennai) and South Asia (Thailand, Myanmar, Sir Lanka) between 2007 and 2016 (40–47). Although the quality of the study designs varied — according to the qualitative assessment carried out by Buhler et al. in 2019 (14) and documented in supplementary material contained in the Appendix — pooled results were positive, showing impact in entomological indicators in intervention areas compared to control areas. DID BI is in accordance with the pooled results reported by Buhler et al. (14), while DID PPI is contrary. The result for DID BI calculated for the study reports a positive result (-6) almost three times higher than the value reported in the efficacy trial conducted by Quintero et al in 2015 (48) that reported a DID of -2.6 and the trial conducted by Kroger et al in Venezuela in 2006 (DID -10). Whereas DID PPI resulted in a negative effect (+0.08) compared to a positive pooled result of (-0.83) reported by Buhler et al. (-1.1) reported by Quintero et al. and (-1.2) reported by Kroeger et al.

The study results of the DOE tended to demonstrate a higher impact on vector indices (BI and PPI) compared to the DID. For example, DOE BI gave a positive result (-15) higher than that reported by Kroeger et al. (-6) but different from Quintero et al., who reported a negative result (+1.3). DOE PPI also showed a higher positive result (-0.35) than that reported in the efficacy trial of Quintero et al. (-0.09) and Kroeger et al. in Mexico (-0.1). The positive findings reported were expected, as container covers with insecticides should result in positive outcomes, both by providing a mechanical barrier for oviposition and adult emergence, and by its insecticidal effect.

The degree of impact in dengue vector indices of the ITM covers is comparable. During 2005, the efficacy trial was conducted under a cluster randomised trial (48) and showed positive results in decreasing vector indices. The scaled intervention (covering more than 5000 households) is still effective in reducing *Ae aegypti* immature indices. Considering that Girardot has 29,278 households (49) and that the intervention covered just 21% of the households, a higher impact should be expected with a higher percentage of intervention coverage. However, a question remains to be answered: Is the intervention sufficient in reducing dengue transmission if higher impact in indices is reached after increasing coverage? Chapter 5 addresses this question by analysing the impact on dengue incidence.

The intervention resulted in a decrease of, on average, between 0.12 (95% CI -0.25,0.01) and 0.26 (95% CI -0.42, -0.10) cases of dengue daily — 1.82 cases per week or 7.8 cases per month or 95 cases per year, according to Kernell and Radius matching method, although not significant. Furthermore, results from a mathematical model of dengue transmission dynamics conducted to investigate the impact of the intervention on dengue incidence in Girardot, Colombia, after evaluating various PPI reduction thresholds from 25%-99%, and simulated at 75% and 100% coverage (50) demonstrated the impact that reducing entomological indices can have on disease incidence. Results of the model reported that scaling up the intervention to cover 75% of the households would result in lowering the total number of cases from 14051 to 1279 and average daily cases from 11.95 to 1 (approximately by 90%). At both 75% and 100% coverage, transmission of dengue would be interrupted almost entirely above 60% reduction in PPI. Given the results of the numerous model simulations, it appears that at 50% coverage of the municipality, there would be relatively little change in the additional decrease in number of cases beyond 25% PPI reduction. Furthermore, at 75% coverage of the municipality, the optimal PPI threshold appears to be 50% with the greatest reduction in total number of cases. The scale-up to 100% coverage of the city does not appear to reduce cases any more than a 75% municipality coverage. Therefore, the optimal threshold for maximum reduction of cases and minimum reduction of PPI appears to be 50% at 75% municipality coverage (21,958 households). However, it is important to note that it may not be feasible to reach this 75% due to the costs involved, and other barriers that have been identified regarding the fidelity of the scaling up process that is investigated further in Chapter 7. However, it is important to consider if the intervention represents a more efficient use of resources compared to routine vector control activities (53).

The study by Taborda et al. (51) evaluated the cost-effectiveness of the intervention, adding evidence for deciding if the intervention could be integrated into routine control interventions. Results reported that *Aedes-Free* intervention generated an additional cost of USD 20.9 per household (costs of regular programme 11.2 vs 32.1 *Aedes-Free +* regular programme*)* and an incremental effectiveness of 0.00173 (reduction of dengue cases). This means that the cost of reducing the probability of dengue infection, with the *Aedes-Free* intervention, would require an investment of $12,097, which could be deemed cost-effective according to a suggested threshold.

Alfonso-Sierra et al. (52) reports on the cost analysis of interventions that focused on controlling the most productive breeding places for *Ae. aegypti* in Latin America. Here, a wide range of costs between 8.20 to 56.6 USD per household was reported. The costs of those interventions, using ITM metallic lids for breeding sites and ITM screens for windows and doors, are the highest.

Peri-domestic and domestic spaces provide different contexts for vector oviposition therefore colonizing different water containers. The study showed that entomological indexes are higher in public spaces than households during pre and post intervention surveys. But pupae productivity is higher in households in both baseline (74% of pupae in households vs 25% in public spaces) and endline surveys (84%% of pupae in households vs 35% in public spaces). Even during the rainy season pupae productivity is higher in households than in public spaces, mainly due to the presence of large ground containers (used for water storage) that produce more than 90% of pupae and therefore considered the key container to be controlled by ITM lids. In public spaces productivity is driven mainly by rain drains that account for more than 90% of public space pupae.

Previous studies conducted in the study area (Girardot) in 2015 by Alcala et al. (1) suggested that the type of *Ae. aegypti* productive containers in households remains stable during different seasons. This study reported that, during the rainy season, households contributed 94% to the total number of pupae, while only 6% were found in public spaces. In the dry season, 98% of pupae were found in households and 2% in public spaces. Large water storage tanks and tanks for washing and storage purposes provided >87% of pupae in households, whereas jars, tyres and sinks contained most pupae in public spaces. High pupae densities were observed in public spaces during the rainy season and in streets and schools in the dry season. There were no significant differences between seasons per pupae indices.

Similar results are reported by Jiménez-Alejo et al., in 2017 (6) in Guerrero (Mexico), who found that more than 97% of containers identified and examined were those used for water storage, and that these contributed the most to the overall pupal productivity in households, even during the rainy season when the mean number of pupae per container was higher in the non-storage containers. But this contrasts with other areas in Mexico. In Merida, non-storage containers were reported to contribute most to the overall pupal productivity rates (54). Multicountry studies conducted in Asia, Africa and Latin America by Tun-lin et al. (39), Quintero et al. (55) and Arunachalam (56) evidenced the variation from place to place. In some study sites (Colombia, Ecuador, Venezuela, Myanmar, Philippines) the large ground containers were the most productive ones, in others (Peru, Mexico, Uruguay, Thailand, Kenya) small containers (buckets, barrels, bowls) where the most productive.

It is important to acknowledge that, while the dynamic of *Ae. aegypti* productivity indoors remains stable, a different situation is seen in public spaces. For instance, Alcalá et al. reported in 2015 (1) that the most productive containers in public spaces were tyres and jars. The present study, conducted 3 years later in the same area, evidenced that rain drains were the most productive containers in public spaces and particularly difficult to assess and control. The local vector control programme focused mainly their activities in public spaces on the collection of discarded containers such as tyres and jars that could produce the displacement of the vector to other suitable breeding sites. This can be explained by the high plasticity of the *Ae. aegypti* population, a colonizer of very unstable settings whose survival is aided by rapid population growth and recovery.

The overall impact of "Girardot *Aedes-Free"* intervention in both households and public spaces was positive but differences amongst study sectors were evidenced. The intervention in households of Sector 2 resulted in a higher impact, as evidenced by the logistic regression model (OR: 0.73 95% CI 0.57-0.92) and by DID BI (Sector 1: -2 vs Sector 2: -7.7) and DID PPI (Sector 1: o.1 vs Sector 2: -0.4) measures. An impact was also observed in public spaces, particularly in Sector 2 that reported an OR of 0.22 (95%CI 0.12 -0.39) and a DID BI (Sector 1: -3 vs Sector 2: -11). Several factors can drive differences in the same geographical or territorial areas. Studies that analyse the spatial and temporal dynamics of vectors have identified and explained the interactions between the conditions and determinants of *Ae. aegypti* vector in different contexts and territorial spaces (57–61). Results show that the spatial and temporal dynamics of dengue and dengue vectors are heterogenous at different intra-urban scales.

As well as environmental factors (ecological niches) there are diverse demographic (urban expansion, demographic composition, urban function) and social and economic factors (economic activities such as tourism, touristic activities, knowledge, socioeconomic stratum and household incomes) interacting at different scales that are associate to dengue incidence and dengue vector presence. Specifically, previous studies carried out in the study area (Girardot) evidenced some of the latter factors. For instance, a study carried out by Fuentes-Vallejo (62) showed that the distribution and incidence of dengue in Girardot is potentially related to the effect of time and space and argued that the distribution might be the related particularly to the economic activities (tourism), urban changes (expansion) and demographic structure. Furthermore, Quintero et al. (63) and Suárez et al. (64) reported that that areas with lower social strata and less educated inhabitants are at considerably more risk of having dengue vector forms in their households. The study was carried out in sectors representing the lowest socio-economic stratum of households (1 to 3 strata) among this the majority (81.6 %,) of household members reported household income between one and two minimum wages (US$ 276= 1 minimum wage) followed by 11.6% that reported household income lower than one minimum wages. The results from the logistic model evidenced that households with household income between 1 and 2 minimum wages are 85% more likely to have immature forms of the vector than those households reporting incomes between 3 to 4 minimum wage.

Additional studies carried out in other urban areas of Colombia, such as Armenia and Arauca (65), determined that vector density in both municipalities is related to their particular ecological and social characteristics. Both municipalities evidenced groups of clusters of *Ae. aegypti* density without a clear trend. In general, higher vector indices coincide with zones with no urban planning, low income strata, high water storage rates, higher mean temperature than the rest of the municipality, and low level of community actions.

Acceptability is an important outcome for the evaluation of intervention effectiveness. In Girardot, ITC acceptability measured through proxy variables was high. The high level of acceptability may be associated with previous work done in former phases of the design of "Girardot *Aedes-Free"* intervention where community participation was a major characteristic. This factor is considered further in Chapter 6 where the process of implementing the intervention at scale is evaluated and acceptability is one of the fidelity factors that affects effectiveness of the intervention.

4.6 Limitations

There were some limitations to this study, firstly the presence of insecticide resistant vectors was not assessed. It is important to evaluate resistance to insecticides in mosquito vector populations as its presence may threaten the effectiveness of the control intervention. Although the water-holding container cover will still act as a barrier. There is scarce information regarding causes and prevalence of resistance in the study site. Insecticide resistance is a growing issue. The information on the causes and prevalence of resistance in the specific geographic areas is scarce, regardless of the fact that such data could help guide vector control programmes on the most effective agents to use in each resistance context (66,67).

An additional limitation was the lack of *Ae. aegypti* adults' forms surveyed, instead, pupal indexes were estimated as a proxy of adult forms. For *Ae.* aegypti it is argued that one of the major factors of failure in control methods is their focus on eliminating immature forms rather than adult forms as the later transit disease. When reviewing study protocol logs it was shown that adult mosquitos were collected with nets. Adult aspirators were not available or were available later in the study. Changing methods will pose a major bias.

Incomplete follow-up may bias the results and as drop-out rates are different between groups (intervention and control). The percentage of loss to follow-up was higher in control groups than intervention (Sector 1: 49% vs 21%; Sector 2: 71% vs 48%)

The time between entomological surveys (baseline and follow-up surveys) was wide (more than 7 months between each). Confounding factors such as climate and regular programme interventions by control services may have played a role influencing vector densities that were not captured.

4.7 Conclusion

This study found that covering *Ae. aegypti* productive household water-holding containers with insecticide lids has a positive impact for controlling *Ae. aegypti* immature production in households. A combination of methods is necessary, particularly combining the targeting of productive containers with other community actions that increase the success in reducing *Ae. aegypti* in both household and public premises.

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Chapter 5 Study 2. Effectiveness of Girardot *Aedes-Free* intervention in reducing dengue reported cases

5.1 Outline

This chapter reports Study 2, by assessing the impact of "Girardot *Aedes-Free"* Intervention in reducing the number of reported dengue cases. Reported dengue cases and associated factors were analysed from available data sets from Colombia's disease surveillance system. Different statistical models were used to estimate the reduction in dengue cases achieved by the intervention. The findings of this chapter have been published in Plos One. The final manuscript is presented in Appendix E.

5.2 Introduction

Ae. aegypti is the principal vector of dengue, Chikungunya, Zika and yellow fever, and is now found on all continents with the exception of Antarctica (1). *Aedes*-transmitted diseases (ATD) account for approximately 23% of the estimated global burden of VBD(2) and pose a significant economic cost in endemic countries—not only for governments that are responsible for case management and the cost of vector control activities but also for households that have to cover their own costs for treatment and protective measures (3–10).

The emergence and resurgence of ATD is associated with complex relationships between a variety of ecological, biological, and social factors of urban and peri-urban environments, all of which are particularly challenging for vector control efforts (11–13). Ecological factors refer to climate (rainfall, humidity, temperature) and also to the man-made ecological setting (unplanned urbanization). Biological factors relate to the behavior of the vector, *Ae. aegypti,* and the transmission dynamics of the various diseases (i.e. the co-circulation of different serotypes) (14). Social factors incorporate a series of influences relating to health systems, including: the weakening of surveillance systems and vector control programs (15); health services (16) and their political context—for example, health sector reforms, decentralization (17); and public and private services such as sanitation and sewerage, garbage collection and water supply. Macro-social events are also important and these include: demographic growth and urbanization; community and household-based practices; knowledge and attitudes and how these are shaped by large-scale forces such as poverty (18,19); social inequality (20); and community dynamics, including human movement (21–23). This complexity highlights the need for setting-specific vector control approaches that combine environmental management practices with community mobilization and engagement, intersectoral and multi-stakeholder partnerships, and principles of Integrated Vector Management (IVM) (24), as well as other country-specific policies, such as the Integrated Management Strategy (IMS) (25). Many community-led interventions have been conducted in Asia but, while results indicate that the interventions reduce vector densities, evidence of impact on dengue transmission is lacking (26).

As mentioned in the introductory Chapter, in response to the increasing threat of dengue, the Ecobiosocial/Ecohealth program was designed by the Special Program for Training and Research in Tropical Diseases (TDR), in partnership with the International Development Research Center from Canada (IDRC) to be implemented in Asia (27) and in Latin American countries (Mexico, Ecuador, Colombia, Brazil and Uruguay) over a 4-year period (28). This initiative carried out a transdisciplinary investigation (Ecohealth approach) of ecological, biological, and social factors of dengue in urban areas, and developed and tested community-based interventions aimed at reducing *Ae. aegypti* breeding sites (29).

Specifically, a cRCT was conducted in the dengue-hyperendemic Colombian municipality of Girardot during 2012-2014 (30). The trial was designed to test the efficacy of long-lasting deltamethrin-treated nets (LLITNde)—used as window/door curtains and as covers on water containers—in reducing the *Ae. aegypti* density measured through the PPI, a proxy for adult density (30). The cRCT compared ten control and ten intervention areas comprising 100 households each. In control clusters, routine vector control activities (larvicides with temephos, health education, and occasional public space spraying of an ultra-low volume of Malathion) were conducted. In the intervention clusters, in addition to the routine vector control activities, insecticide-treated curtains were hung over windows and doors, and covers were placed over the most *Aedes*-productive water containers. Results demonstrated that, in the intervention clusters, PPI declined by 60% after the intervention with ITN covers. In light of the results of this trial, and following the recommendations of the 2017 WHO response strategy (2), the Colombian program decided to extend the intervention in Girardot aiming to achieve not only a broader reduction in *Ae. aegypti* vector densities but also impact on dengue transmission. A key strategy to ensure the intervention's long-term viability was a multisectoral action approach implemented across different sectors (health, social development, tourism, academic and education).

Here, I investigate the effectiveness of the scaled-up *Ae. aegypti* control intervention ("Girardot *Aedes-Free*) in reducing the number of reported dengue cases in Girardot, Colombia, between 2015 and 2017.

5.3 Methods

5.3.1 Setting

The study was conducted in Girardot (4°18′02″N 74°48′27″W), Colombia, which is 134 km from the capital, Bogotá. Girardot is located 289 meters above sea level, has an annual average maximum temperature of 33.3 °C, a relative humidity of 66.38%, a mean annual precipitation of 1,220 mm, and two weather seasons during the year: the dry season (January to February and June to September) and the rainy season (March to May and from October to December). Girardot´s population is around 105,085, living in 23,885 households (97% of which are urban) and distributed over 130.32 km^2. The population triples during the weekends, as Girardot's main economic revenue is tourism.

Girardot presents an eco-epidemiological and social niche favourable for sustained transmission of dengue (13,31), Chikungunya and Zika. The circulation of multiple dengue serotypes has been reported (32,33). Between 2005 and 2016, 5,928 dengue cases (residents and non-residents) were reported to the surveillance system of which 5.78% were severe. For this same period, an average of more than 500 dengue cases were reported annually (range 81-1163). In 2013, 1,103 cases were reported, 532 in 2014, and 364 in 2015. The age-groups with most dengue cases were 5-9 and 10-14 years old (SIVIGILA 2005-2018). With respect to Chikungunya, the first case in Colombia was identified on September 11, 2014, and in Girardot in December 2014. By the end of 2015, Girardot had reported 8,905 cases of Chikungunya, representing an annual incidence of 8,416 per 100,000 inhabitants (34). Additionally, by the end of 2016, 1,936 cases of Zika with an overall attack rate of 18.43 per 1000 inhabitants (35).

Ae. aegypti has been reported as the principal dengue vector in Girardot (31,36) and in other dengue hyperendemic municipalities of Colombia (Armenia, Arauca, Anapoima). The studies report vector productivity associated with storage of water in large and uncovered low level cement containers known as "albercas", which are estimated to account for more than 70% of pupae production (36-38).

5.3.2 "Girardot Aedes-Free" intervention

As described in Chapter 3, the intervention focused on four setting levels (household, school, community and institutional) where diverse actors interacted and participated with different intervention components together with the control program activities. This intervention was developed and scaled up following an Ecohealth approach (29) and was detailed in Chapter 3. The scaling-up of the intervention occurred in three phases: 1. Pre-implementation phase; 2. Active implementation; and 3. Sustainability phase. Table 1 describes and compares the characteristics of the "Girardot *Aedes-Free"* and routine vector control interventions.

Table 5.1. Characteristics of "Girardot *Aedes-Free*" intervention and routine dengue control programme in Girardot, Colombia

Characteristics	Girardot *Aedes-Free*	Routine dengue control programme
Actions	*Household level:* Targeted intervention: insecticide-treated covers with aluminum frames or elastic band for *Ae. aegypti* productive water-holding containers. *School level:* Community mobilisation by students from public schools. *Community level:* Community mobilisation by presidents of community boards. *Institutional level:* Multi and intersectoral committee for the prevention and control of VBD.	Daily physical inspections of water-holding containers registering presence and absence of *Ae. aegypti* immature forms. Temephos in tanks. Health education for behavioural change Focal study of severe dengue cases: identification of dengue positive households and surveillance of 40 surrrounding households for spatial fogging, including public spaces.
Human resources	1 field supervisor (environmental engineer). 1 field coordinator (environmental engineer). 4 field technicians (environmental engineers).	11 vector- borne technicians, 1 coordinator, 2 undergraduates as educators.
Household visits	33% of the total of households in each sector (1 and 2) with productive containers.	200 household visits per week, 40 per day in Girardot.
Indices collected	Immature (presence/absence and pupae per person index) and adult forms.	Presence/absence of immature forms.

For household level actions, all the urban area of Girardot was divided into 4 sectors. A sector was defined as an area that included several neighbourhoods with similar ecological and sociodemographic characteristics. Each sector was divided into intervention, buffer (100 meters), and control zones. The active phase in sector 1 was carried out from December 4, 2015 until November 18,2016, followed by sector 2 that was carried out between September 14th 2016 and February 24, 2017. Sectors 1 and 2 represent less than 20 % (25.2 Km^2) of the total of the urban area of Girardot (130.32 km^2) and correspond mainly to socioeconomic strata 2 and 3 followed by stratum 1 (Figure 5.1). During the active implementation phase, 3,898 insecticide-treated aluminum covers were distributed to 2,935 households (1.32 covers per household) and 1,774 round elasticized covers to 965 households (1.84 per household).

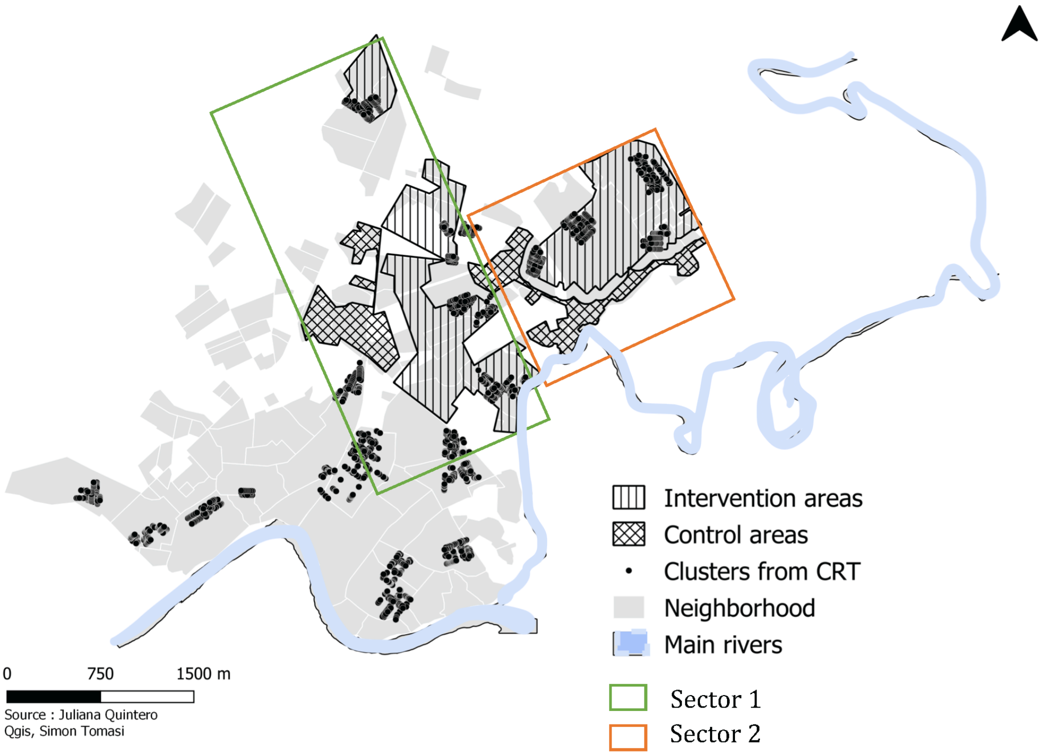

Figure 5.1. Map of Girardot and study sectors 1 and 2

5.3.3 Study design

An ecological study was proposed to evaluate the impact of "Girardot *Aedes-Free*" intervention in reducing notified dengue cases.

5.3.4 Data sources and analysis

Daily dengue surveillance data for the study period January 2010 to December 2017, were obtained from the Communicable Disease Surveillance System of Girardot, Colombia (SIVIGILA), where dengue cases are recorded in line with a standard case definition (39). Cases are identified and reported by the health system as either ‘probable’ dengue, ‘probable severe’ dengue or ‘lab confirmed’ (39). Population data for incidence calculation was obtained from the National Administrative Department of Statistics of Colombia year 2008. The analysis of dengue cases was conducted over a period of 8 years (2010 -2017 33rd epidemiological week). Cumulative incidence was also calculated from the total number of dengue cases notified divided by the respective population at risk and then multiplied by 100,000. This incidence was expressed as: total number of dengue cases/total population*100,000.

The effectiveness of the intervention was assessed using quasi-experimental analysis. Differences were modelled comparing numbers of clinically reported and lab-confirmed dengue cases (primary outcome) among intervention implementation points (before–after) using: 1. Propensity Score Matching (PSM) (40,41), 2. Autoregressive Moving Average (ARMA) and 3. The Diff-in-Diff method, modelling differences between numbers of dengue cases adjusted for population size in each sector during scaling-up phases (pre-implementation vs sustainability) and between treatment groups (intervention and control areas). All the statistical analysis was conducted using Stata software, version 15 (42).

1. PSM

PSM consists of the following steps:

a. Estimate the probability that a day would be treated conditional on a set of regressors. The probability is calculated by estimating the coefficients of the model $P(D=1|X)=\Lambda(XB)=\frac{e^{XB}}{1+e^{XB}}$. The coefficients were calculated by maximizing the following likelihood function $\mathcal{L}(y_1,\ldots,y_n)=\sum_{i=1}^{n} y_i \ln(\Lambda(XB))+y_i(1-\Lambda(XB))$.
b. Check if the score is balanced.
c. Match each treated day with one not treated. For this, the following matching algorithms were used:
    i. Nearest neighbour matching: Select a pair of control and treated observations that minimize the following expression
    $$\text{Min}\,\|p_i-p_j\|$$
    ii. Radius: Select a pair of control and treated observations that fulfil the following expression
    $$\|p_i-p_j\|<r$$
    iii. Kernel (Bartlett): Each observation is matched with several observations as:
    $$H(i,j)=\frac{K\left(\frac{(p_j-p_i)}{b}\right)}{\sum_j K\left(\frac{(p_j-p_i)}{b}\right)}$$

Where b is the bandwidth. All alternatives were estimated using common support, a further requirement besides independence.

d. Estimate the average impact of treatment on the treated.

2. ARMA

Because the data have a temporal structure, the estimation of an ARMA model (p, q) was performed. The number of cases is the dependent variable.

$$CN_t = \frac{e_t \beta(L)}{\alpha(L)}$$

Where L is the lag operator, i. e. $x_t L^k = x_{t-k}$ and the expressions $\beta(L)$ and $\alpha(L)$ are lag polynomials of order q and p respectively. Using the autocorrelation function, partial autocorrelation, and unit root tests, it was determined that the time series has an ARMA structure (2,0,3). To determine the influence of the treatment on the number of cases, a dummy variable was included in the ARMA representation, in the form:

$$CN_t = c + \alpha_1 CN_{t-1} + \alpha_2 CN_{t-2} + \alpha_3 CN_{t-3} + e_t + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \beta_3 e_{t-3} + \gamma D_t$$

After the estimation, several diagnostic tests were performed. The estimate is stable, invertible, and its residuals are not autocorrelated.

3. Diff-in-Diff

Differences in numbers of dengue cases (primary outcome) between scaling-up phases (pre-implementation–sustainability) and between treatment groups (sectors 1 and 2) were estimated.

Initially, dengue cases were geo-localized with the variable “address” using the SIVIGILA data set (78% of the cases were possible to localize). Then the number of dengue cases per sector was identified in the intervention and control areas using QGIS software (v. 2.18). The QGIS command `Join attributes by location´ was used to create a new vector layer containing information on the number of cases per sector and intervention area (43).

A linear regression model was used to estimate the effectiveness of the intervention in the presence of associations between sociodemographic factors reported in the SIVIGILA data set (age, sex, ethnicity and type health insurance scheme (as a proxy of socioeconomic status). In Colombia there are three types of health insurance schemes: contributory plan for employees and self-employed workers with contributory capacity, a subsidized (non-contributory) scheme for informal workers and low-income self-employed workers and an uninsured for unemployed.

A descriptive analysis of baseline and follow-up characteristics was performed for each study group and differences between these characteristics were assessed by bivariate analysis, using a test of proportions. Categorical variables were summarized as frequencies and numerical variables as means with standard deviations if normally distributed, or as medians with interquartile ranges (IQRs) if non-normally distributed. The regression model used the number of cases as parameter estimates grouped per day. The effect of the intervention was tested as the effect-difference from baseline to follow-up between the intervention and control areas. Significance was calculated at < 0.05 and 95% confidence intervals reported.

5.1 Results

5.1.1 Description of dengue cases in Girardot, 2010-2017

Between 2010 (1st epidemiological week) and 2017 (33rd epidemiological week), 3,193 suspected dengue cases were reported to the surveillance system of Girardot, of which 99.6% were clinically classified as dengue. During this period, a mean of 1.93 dengue cases were reported per day (range 1 to 14), although only 198 (6.2%) were laboratory-confirmed. Figure 5.2, shows three outbreaks over the course of 8 years. During 2010, 487 dengue cases were reported, 708 cases in 2013 and 532 in 2014.

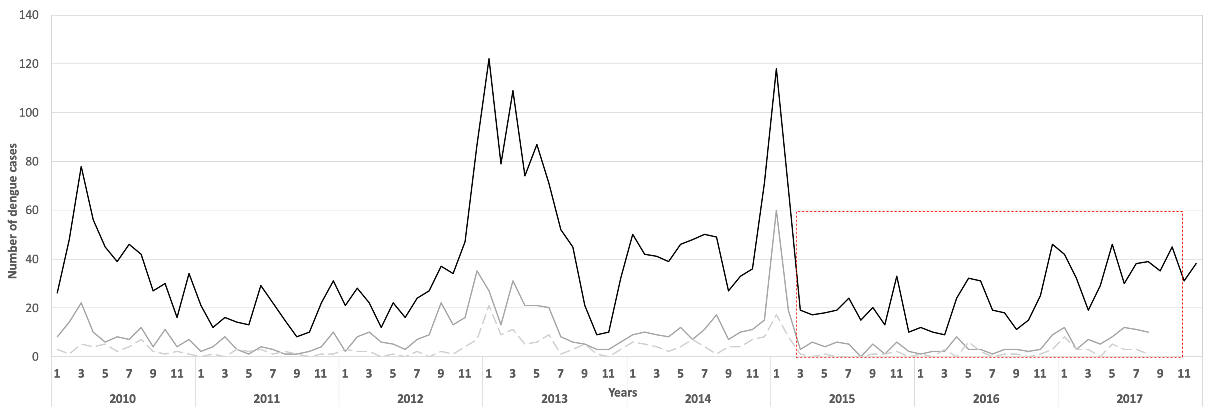

Figure 5.2. Number of reported dengue cases in Girardot, Colombia reported between 2010-2017

The solid black line shows the number of dengue cases in Girardot between 2010 and 2017. The solid gray line shows the number of dengue cases in the intervention areas of study sectors 1 and 2. The dashed grey line shows the number of dengue cases in control areas of study sectors 1 and 2. The red square indicates the scaling-up period.

5.1.2 *Description of notified cases in Girardot, during scaling-up of the intervention*

During the period of July 2015 to August 2017 (Setup phase: baseline; Active phase: implementation and Sustainability phase: follow-up) 628 dengue cases were reported in the SIVIGLA of Girardot (Figure 5.3).

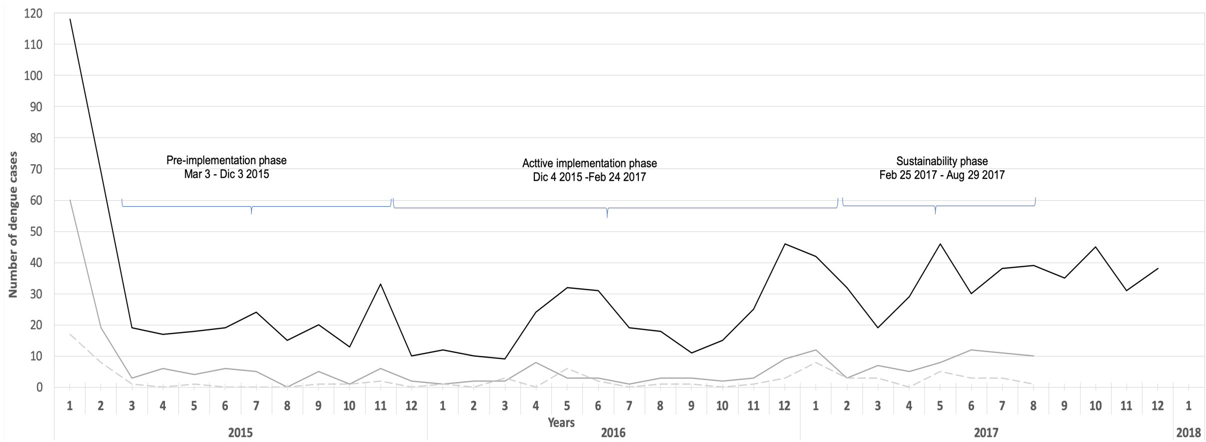

Figure 5.3. Intervention Scaling-up timeline

The solid black line shows the number of dengue cases in Girardot between 2015 and 2017. The solid gray line shows the number of dengue cases in intervention areas of study sectors 1 and 2. The dashed gray line shows the number of dengue cases in control areas of study sectors 1 and 2.

19% (121) of dengue cases were from the study sectors. 69 dengue cases were reported during baseline and follow-up in Sector 1, and 52 cases in Sector 2. During baseline dengue cases were lower on the control area, 11 dengue cases were reported in the intervention area of Sector 1, compared to 3 cases in the control area.

A similar situation was observed for Sector 2, where 14 dengue cases were reported in the intervention area, compared to 3 cases in the control area. Dengue incidence was generally higher in Sector 1 (526.2 per 100,000 inhabitants) compared to Sector 2 (381.6 per 100,000 inhabitants). For all sectors, the incidence was higher in the control area (529.01 per 100,000 inhabitants) than the intervention area (371.32 per 100,000 inhabitants). There was an increase in dengue incidence reported in both intervention and control areas from baseline to follow-up. The increase in dengue incidence per 100,000 inhabitants for all sectors was greater in the control areas (an increase of 396.75 cases per 100,000 inhabitants) than in intervention areas (an increase of 267.02 cases per 100,000 inhabitants). In Sector 1, the increase in dengue incidence was higher in control areas (an increase of 483.33 cases per 100,000 inhabitants) than in intervention areas (an increase of 377.43 cases per 100,000 inhabitants). In Sector

2 the incidence in control areas did not change from baseline to follow-up (236.07), but the incidence from baseline to follow-up in the intervention area increased almost two-fold (Table 2). Table 5.2 describes the distribution of reported dengue cases in the intervention and control areas during baseline and follow-up surveys (n=121).

Table 5.2. Dengue cases and incidence per intervention (I) and control (C) areas during baseline and follow-up surveys, Girardot 2015-2017.

Sectors	**1**				**2**				**All sectors**			
Areas	**I**		**C**		**I**		**C**		**I**		**C**	
Population	9,538		3,931		14,430		2,118		23,968		6,049	
Number of dengue cases (*)	47 (492.76)		22 (559.65)		42 (291.06)		10 (472.14)		89 (371.32)		32 (529.01)	
Time of Survey	**BL**	**FU**	**BL**	**FU**	**BL**	**FU**	**BL**	**FU**	**BL**	**FU**	**BL**	**FU**
Number of dengue cases per sector	11	36	3	19	14	28	5	5	25	64	8	24
Incidence per 100,000 inhabitants	115.32	377.43	76.31	483.33	97.02	194.04	236.07	236.07	104.30	267.02	132.25	396.75
Mean age	25.63		32.63		28.66		23.8		27.06		29.87	
SD	24.36		25.26		24.64		26.69		24.40		25.62	
Sex												
F	22 (46.80)		10 (45.45)		16 (14.28)		5 (50.00)		38 (42.69)		15 (46.87)	
M	25 (53.19)		12 (54.54)		26 (61.90)		5 (50.00)		51 (57.30)		17 (53.12)	

BL: baseline; FU: Follow-up; SD: Standard deviations; F: female; M: male. * Incidence per 100,000 inhabitants**.**

5.1.3 *Effectiveness of the intervention in reducing dengue cases*

The PSM analysis indicates that the intervention resulted in a decrease of an average of between 0.12 (-0.25,0.01) and 0.26 (-0.42, -0.10) cases of dengue daily (1.82 cases per week or 7.8 cases per month or 95 cases per year) in Girardot (Table 5.3). By the same means, the time series analysis suggests that the treatment (Girardot *Aedes-Free* intervention) on average decreased the number of dengue cases by 0.27 cases daily (Table 5.4).

Table 5.3. Average treatment effects estimation using Radius and Kernell matching method

Matching method	Number of treatments	Numbers of controls	ATT	95% CI	t
Kernel (attk)	215	1414	-0.122	-0.25, 0.01	-1.830
Radius (attr)	215	1414	-0.263	-0.42, -0.10	-3.170

Number of observations = 1629; Replications = 2500; ATT: Average treatment effect on the Treated group; CI: Confidence Interval.

Table 5.4. Number of dengue cases after intervention implementation estimated by ARMA model.

Variables	Coefficient	95% CI	*p*-value
Constant	1.86	1.50, 2.22	<0.0001
Intervention	-0.27	-0.95, 0.41	0.436
ARMA parameters			
AR (1)	1.68	1.25, 2.10	<0.0001
AR (2)	-0.68	-1.10, -0.261	0.002
MA (1)	-1.54	-1.97, -1.11	<0.0001
MA (2)	0.54	0.19, 0.89	0.002
MA (3)	0.01	-0.06, 0.09	0.721
Sigma	1.23	1.20, 1.26	<0.0001

AR: Auto Regressive; MA: Moving Average; CI: Confidence Interval.

The Diff-in-Diff estimator reports an increase of 0.065 dengue cases daily (0.455 per week, 1.95 per month) (Table 5.5) but, when calculating the differences in incidence rates and rate ratios during sustainability (follow-up phase) among intervention and control areas of both sectors (see Table 5.2), an incidence rate difference of –0.0129 (95% CI -0.00179- -0.00078) and an incidence rate ratio of 0.674 (95% CI 0.577 – 0.786) are observed.

Table 5.5. Difference-in-Difference estimation results from Sectors 1 and 2, Girardot

Outcome variable	Dengue cases	Standard Error	95% CI	*p*-value
Baseline				
Control	0.929			
Treated	0.989			
Diff (T-C)	0.060	0.069	-0.076, 0.196	0.387
Follow-up				
Control	0.950			
Treated	1.075			
Diff (T-C)	0.125	0.086	-0.044, 0.294	0.151
Diff-in-Diff	0.065	0.112	-0.152, 0.281	0.557

R-square: 0.06, Means and Standard Errors are estimated by linear regression, Number of observations in the Diff-in-Diff: 173. Adjusted by age, sex, season, and health insurance.

5.2 Discussion

The principal goal of any dengue intervention is to reduce disease incidence and transmission by reducing human exposure. *Ae. aegypti* control remains the primary tool available to achieve the latter goal. Several systematic literature reviews published in the last decade (26,44–47) have reported the impact of dengue vector control measures and concluded that the most effective are community-based interventions that combine: 1. Social mobilization with participation in local government control services and joint collaboration in environmental management or clean-up campaigns, 2. Water covers and window screens using insecticide-treated nets and 3. The use of larvicides.

The efficacy of dengue vector control interventions is principally measured using entomological parameters (indicators of vector infestation), however, the reviews pointed out that these indicators do not always accurately reflect dengue transmission (48,49). The studies that include epidemiological risk indicators to determine the effect of a dengue vector control intervention mainly use interrupted time series, propensity score matching, and classic, spatial, and Bayesian statistical analysis (50–52).

This ecological study assessed impact of a dengue vector control intervention in Girardot, Colombia, in reducing reported dengue cases and incidence. When analysing the data on dengue cases it was observed that outbreaks occur every three years and, importantly, the number of cases per season differs, with more cases reported in dry seasons than in rainy seasons. Although the dry season includes 7 months (December through to February and June through to September) and the rainy season includes only 5 (March through to May and October through to November), the former still has a higher mean number of cases per month. High temperatures, relative humidity, and precipitation are recognized factors implicated in dengue transmission (53,54), facilitating *Ae. aegypti* population growth. In Girardot, there is an additional dry season factor—tourism. The presence of susceptible populations and a higher population density during the dry seasons favours virus transmission and so the effect of tourism on the increase of dengue cases reported during this season must be evaluated.

Despite low dengue transmission reported during the intervention phases, the results indicate that, compared to control areas, intervention areas reported a lower dengue incidence over the 5 to 13 months, although in both areas the incidence increased. The sector-by-sector differences in dengue incidence after the implementation phase may be due to the reduced use of container covers over time. The follow-up period was of 5 to 13 months in sector 1, and 6 to 10 months in sector 2, after intervention implementation. A variety of studies have suggested that the use of an intervention tends to decrease over time (55–57). As with any vector control measure, a consistent level of compliance is required by household members to ensure the sustainability of the intervention's impact (58,59). There is a need to identify factors to achieve permanent changes in human behaviour. Moreover, the percentage of productive container coverage per sector never approached 100%. Sector 1 had 39.54% of coverage and Sector 2 50.39% of coverage. Higher coverage than this is needed for an intervention to have a broader impact (55–57). The main reason for the limited coverage was the inaccessibility of participant houses, even after three visits. Because Girardot is a tourist destination, many of the residences are "second homes" for residents of other cities who visit for leisure purposes (37).

More than half of the study population comprised children who attend school during the daytime. Schoolchildren participated in mobilization activities but not breeding-site interventions, nor were screens for classrooms implemented in schools. Another important age-group were young men and women who spent significant proportions of time in places of work and recreation, neither of which were included as intervention sites. A growing body of evidence (22,60–62) has shown that human movement is an important factor to consider when analysing the effectiveness of vector interventions and understanding dengue epidemiology. Previous studies have shown that transmission of dengue virus appears to be largely driven by infections centered in and around the home, with the majority of cases related to one another occurring in people who live less than 200 meters apart, supporting a role for targeted vector control around the residences of detected cases (63). Furthermore, it is important to consider other locations where individuals tend to gather and spend significant amounts of time, as they may play an important role in the virus cycle. Sites such as schools pose a risk of transmission as there may be abundant breeding containers for *Aedes* vectors and will contain an aggregation of students during the daytime (64–66).

Defining effectiveness is one of the elements for scaling up an intervention into public health policies. However, other criteria are equally important, including acceptability, reach, adoption, ease of delivery, alignment with local policies and cost (67–69). Further analysis of the fidelity (70–72) among other implementation factors that are addressed in Chapter 6.

5.3 Limitations

Using secondary quantitative information of notified dengue cases from SIVIGILA presented several challenges, as has been evident in studies in other countries, such as Colombia (32,73–75). The surveillance system only captures symptomatic patients who go on to seek treatment at health care services and are registered with a residential address that is not necessarily the location of dengue transmission. In addition, no specific serotype information is reported. Another limitation is the available spatial information (road network, neighbourhoods and blocks) and the address and neighbourhood fields in the SIVIGILA database required for identifying dengue cases. The address and neighbourhood fields are not standardized and filtering information was needed to decrease error when localizing each dengue case by sectors and intervention and control areas, but 78% of dengue reported cases were able to be geo-located, underestimating the true incidence.

In addition, during intervention dengue incidence decreased, albeit following the trend of dengue peaks in Girardot and elsewhere every three years. It would be expected that, during higher periods of dengue incidence, the intervention impact would have been higher than the incidence reported in the follow-up. The decrease of dengue cases during the scaling-up phase could be a long-term result from previous interventions carried out in Girardot since 2012, combined with enhanced vector control actions implemented by the local health authorities due to the re-emergence of Chikungunya and Zika viruses.

5.4 Conclusion

The aim of dengue vector control is to maintain *Ae. aegypti* populations below or close to minimal transmission thresholds, slow the force of dengue-virus transmission, and reduce sequential infections with different serotypes. This study evaluated an intervention for its capacity to reduce notified dengue cases by targeting the most productive dengue vector containers. The results indicate a reduction in dengue incidence compared to matched control sites, although this is probably an underestimate of the true potential of the intervention considering that approximately 20% of cases were not identified for analysis. Greater coverage—in particular, reaching other sectors and other high-risk transmission areas (public spaces such as schools and commercial recreation sites)—and an improved surveillance system are required for maximizing the effect of the intervention.

5.5 References

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Chapter 6 Study 3. Evaluation of the process of scaling-up and implementation of Girardot *Aedes-Free* intervention

6.1 Outline

This chapter refers to Study 3, which aims to document and analyse the process of scaling up and implementing Girardot *Aedes-F*ree intervention by clarifying the causal mechanisms and by examining the factors that enable or constrain it. The process and approaches used, the challenges found, and the lessons learned will be explored. This analysis of the study is important as it ensures that the observed proximal and distal outcomes (reduction of *Ae. aegypti* density and dengue cases) are linked to the scaled-up intervention and allows us to generate ideas to improve the process of the intervention at scale and inform other VBD interventions.

6.2 Introduction

The efficacy and effectiveness of programs and projects has been one of the most essential parts of the Millennium Development Goals replaced in 2015 by Sustainable Development Goals, with a need to pool resources to scale-up projects that have a positive impact. Since 2003, the ExpandNet, an international network supported by the WHO, has been tackling the question of program/project/intervention efficacy. The goal of the network is to ensure that high-quality health-care treatments be scaled up to serve more people, more rapidly, and more sustainably. It is a global leader in scaling up projects, having created the ExpandNet conceptual framework for scaling up (1) and making recommendations to help with the process (2).

ExpandNet/WHO defines scaling up as: "deliberate efforts to increase the impact of proven successful health innovations so that they benefit a greater number of people, foster long-term policy and program development " (1,3) and generate sustainable institutional capacity (2). The framework is guided by the following principles: systems thinking, a focus on sustainability, the need to determine the feasibility of scaling up, and respect for gender, equity, and human rights. The framework outlines the fact that the evidence-based 'innovation' being taken to scale needs to consider four elements: the resource team, user organisations, scale-up strategies, and the environment.

Four types of scaling-up are considered; spontaneous, guided (horizontal or vertical) and diversification. The first refers to spontaneous diffusion, which starts from an innovation that moves to another context. This usually occurs when the innovation offers a solution to a problem in a different place from where it was originally made. Guided scale-up can be horizontal scaling, when an innovation is replicated to serve new populations or is expanded into new geographical areas; political or vertical scaling up, when a government makes the decision to adopt an innovation at the national or sub-national level and it is institutionalised through planning mechanisms or changes in public policies. And diversification, where the new innovation is added to existing interventions (1,2,4).

The framework also outlines key scale-up strategies. Strategies refers to plans and actions needed to establish innovation in policies, programmes, and service delivery (strategic decisions related to the type of scale-up). ExpandNet/WHO recommends simplifying innovation, building training capacities in organisations, connecting scaling up with health sector reforms, working with local leaders or politicians to gain acceptance for innovation (advocacy), planning how to address human resource shortages (cost and resource mobilization strategies) and monitoring and evaluation strategies. In addition, the framework also highlights the need to assess opportunities and barriers for scaling up within the environment. These include political, socioeconomic, and cultural factors as well as people's needs (1,2,4). This systematic approach proposes a scaling -up process in three phases or stages. Phase 1 comprises the design and conduct a pilot project of the intervention to be evaluated, with a scale-up in mind to address efficacy and scalability. Phase 2, develop a participatory scaling-up strategy (scaling-up plan) once the intervention has demonstrated a degree of efficacy and or effectiveness. Finally, Phase 3emphasises the process needed to strategically manage the scaling-up process. This will include a review of the scaling strategy developed in stage 2 to plan action to fulfil the gaps and restrictions faced during the process.

Within the Ecohealth Leadership Initiative for Vector-Borne Diseases in Latin America and the Caribbean (5,6), scaling-up interventions experiences were developed from the Ecohealth approach for the prevention and control of dengue, malaria and Chagas disease in Colombia, El Salvador, Guatemala, Honduras, Mexico and Venezuela. Prior to the scaling-up phase, these projects went through baseline phases, construction of the interventions with the participation of local communities and stakeholders, and finally pilot testing of the interventions. These projects have disseminated their results in articles and congresses (7–15) but less literature is found on the processes and factors associated with scaling-up of these experiences.

This case study seeks to identify and analyse the scaling-up and implementation processes of "Girardot *Aedes-Free"* intervention in a local hyperendemic municipality of Colombia to determine the key elements that enable or hinder the strategy, to develop the potential to scale-up other vector control interventions.

6.3 Methods

An evaluation of the process of scaling-up and implementing the intervention was conducted guided by the Medical Research council (MRC) process evaluation guideline (16–18) and the ExpandNet/WHO Framework (1). Both frameworks allow to elicit information about the process of implementation including probes of implementation fidelity "*the degree to which . . . programs are implemented . . . as intended by the program developers*", and identify the factors that enable and/or constrain the scaling up of the intervention. The fidelity dimension was complemented following the implementation of the fidelity framework (18,19). These are important elements that may influence the relationship between the intervention being scaled-up (implementation of the intervention scaled-up), mechanisms, context, and its intended outcomes.

In addition, it is important to acknowledge that the intervention was designed following an Ecohealth approach (6). This is a research approach and platform for carrying out actions in health and shares several elements with the scaling-up framework. Mainly, it recognises the need for innovative solutions, which, in the context of Ecohealth, is identified as the application of new methods, ideas, forms of evaluation technologies or processes of novel development. It also promotes working with multiple sectors, agencies, and actors, governed by the principle of bringing knowledge into action to improve people's health and well-being. Ecohealth and scaling-up initiatives are interested in identifying local processes and shared interests and actively linking with the community and local institutions.

6.3.1 Study design

A case study with a mixed methods design was conducted (20,21). Quantitative and qualitative data were merged to provide a comprehensive analysis.

6.3.2 Data sources

Quantitative data were obtained from follow-up questionnaires administered to 1,163 household members between January 17th and December 13th, 2017) and from study project logs providing intervention description, monitoring data and participant responsiveness. Qualitative data were obtained from documents related to the context and from 40 semi structured interviews that followed an interview guide presented in Appendix E Interviews were conducted throughout November 2016 and August 2017, to 18 community members (householders living in intervene sectors), seven community leaders, nine members of research team (ITCs implementers, field staff and school students) and six stakeholders (local health authorities). The mean age of the interviewees was 42 years and 63% (25) of them were women. The later key informants (KI) were selected based on their involvement in the research, or in other vector control activities within the municipality by purposive and snowball sampling and the selection considered theoretical saturation (22). KI were providers who had the perspectives about the intervention implemented, researchers who guide and monitor the implementation of the intervention, government officials (health secretariat, public health director, vector control programme coordinator and technicians) and community members as beneficiaries, school students who act as intervention mobilizers, and officials of non-governmental organizations or from private organisations.

6.3.3 Data management and analysis

For information resulting from the study logs (follow-up surveys) quantitative descriptive analysis was conducted. Categorical variables were summarised as frequencies and numerical variables were summarised as means using Stata 16 (23).

The information obtained from the semi-structured interviews was transcribed word by word and analysed in NVivo (NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12, 2018.) The information was organised into words, phrases and paragraphs that were found to be related to the categories defined in Table 6.1. Each category also relates to each of the categories that the frameworks propose as illustrated in Appendix F. For all categories included in the analysis, theoretical saturation was considered. Emerging subcategories identified during the collection process and analysis of the interviews were also included (limiting and facilitating factors). To assess fidelity, what happened was compared with the defined specific intervention descriptors proposed in Chapter 3.

Table 6.1. Definition of predefined categories

Categories	**Definition**	**Subcategories**
1. Innovation *	Intervention that is being scaled-up: "Girardot *Aedes*-Free intervention under multisectoral approach described in chapter 3.	Intervention complexity: degree of multiple interacting components, and non-linear causal pathways CORRECT attributes (credible, observable, relevant, relative advantage, easy to install and understand, compatible, testable) (3).

2. Environment	Anything external to the intervention that may act as a barrier or facilitator to its implementation at scale. Policies, socio-economic and cultural conditions, people's needs and perceptions.	Political context Economic context Disease context
3. Resource team	All the stakeholders or institutions/organisations involved in the promotion and facilitation of the scaling-up and the use of the intervention, mainly: researchers, programme managers, service providers, policy makers, and representatives of other governmental organisations, NGOs, or private institutions.	
4. User organisation	Institution (s) or organisation (s) that are expected to adopt and implement the intervention on a large scale.	Responsiveness
5. Scaling-up strategy	The plans and actions required to establish the intervention in policies, programmes, and service delivery.	Facilitation strategies (provision of manuals, guidelines, training, and monitoring and feedback for implementers) Community participation Intersectoral collaboration Strategic choices related to: • Type of scaling up • dissemination and advocacy • Organisational process • Costs and resource • Mobilization monitoring and evaluation
6. Fidelity	Whether "a programme service or intervention is being delivered as it was designed or written"	Adherence Coverage Dose

	By intervention components	Frequency Duration Adaptation
7. Mechanisms	Factors that affect, or moderate positively or negatively, the implementation process and its degree with which an intervention is implemented.	Quality of delivery Participant responsiveness (How far participants fully accept and use the intervention, how far they perceive the intervention to be useful and how individuals responsible for delivering It responded) Intervention complexity Context

* The first category was assessed by developing the theory of change (presented in Chapter 3) that gave a clear description of the intervention, including how it was implemented, and how it was expected to work.

6.4 Results

It is clear from the review of several research records that "Girardot *Aedes-Free"* intervention followed the ExpandNet/WHO framework´s three stages with varying degrees of implementation. It started with the pilot test to determine its efficacy and scalability (24), followed by the development and implementation of the scaling-up strategy presented later in this chapter. In the second stage, a participatory and multisector process was attained, and different strategic choices were considered. The last phase (phase 3), which demands managing the scaling-up process, was not evidenced but the analysis carried out will provide evidence of key lessons emerging at each stage.

Results will be presented following the categories and subcategories proposed in Table 6.1 and categorised later in Table 6.4 as factors that hindered or enabled both the scaling-up process and the implementation of the intervention.

6.4.1 The Innovation ("Girardot Aedes-Free" intervention)

The core components of "Girardot *Aedes-Free"* Intervention were described and operationalised as presented in Chapter 3. The intervention revolved around four components (mobilisation and joint collaboration of actors and sectors, operational planning, community actions and monitoring, and evaluation) implemented during three phases. The interaction of these components aimed at increasing awareness and knowledge on dengue and its vector, as well as strengthening the capacity for action through multi and intersectoral collaborations. The expected distal effects were the institutionalisation of the intervention in the local vector control programme, multi and intersectoral actions for the continued control of *Aedes aegypti,* leading to a reduction in the density of the dengue vector, and fewer reported dengue cases.

The "CORRECT" attributes of "Girardot *Aedes-Free"* intervention are presented in Table 6.2. "Girardot *Aedes-Free"* intervention has many of the attributes needed for a successful scaling-up process. "Girardot *Aedes-Free"* intervention is **C**redible as it was conducted by Fundación Santa Fe de Bogotá (FSFB), a respected health institution, in co-coordination of other academic local institutions. The intervention is **R**elevant as it provides a sound and adapted solution to address a disease with high burden in the municipality such as dengue and potentially other arbovirus of recent introduction in the country (Chikungunya and Zika). "Girardot *Aedes-Free",* specifically the environmental component of the intervention, offers a **R**elative advantage as it confers a long-lasting protection to the most productive vector breeding site with a net. However, container covers are not **E**asy to install and are costly due to the diversity of water tanks shapes and require training and expertise to customise. Other components of the intervention, such social mobilisation and raising awareness provides opportunities to reach and engage community members. "Girardot *Aedes-Free"* intervention is **C**ompatible with existing national and local priorities of arboviruses prevention in Colombia. "Girardot *Aedes-Free"* intervention, and similar *Aedes* control interventions using ITM (25–29) have been **T**ested for their efficacy in cluster randomised trials. Furthermore, additional evidence of the effectiveness in reducing *Ae. aegypti* indices and reported dengue cases is shown in Chapters 4 and 5.

Table 6.2. CORRECT characteristics of "Girardot *Aedes-Free"* intervention

Intervention attribute	Key Questions for Scale-Up*	Girardot *Aedes-Free* intervention
Credible	1.Have results of pilot testing the innovation been documented? 2. How sound is the evidence? 3. Is further evidence/better documentation needed? 4.Has the innovation been tested in the type of setting where it will be scaled up?	cCRTs have been conducted in the study area and in similar setting in other Latin American countries as documented in the introduction of Chapter 5. Effectiveness of the intervention was documented in Chapter 4 and 5 for 2 of the 4 sectors where the intervention was implemented. Research was conducted by credible researchers in directly relevant settings in Latin American countries.
Observable	1.How observable are results?	Results from the cCRT (pilot study) are unequivocal in demonstrating lower *Ae. aegypti* indices (PPI). Less evidence is available for reduction in dengue cases and dependent of the sustainability of the intervention.
Relevant	1.Does the innovation addresses a felt need, persistent problem, or policy priority?	*"Girardot Aedes-Free"* addresses the persistent problem of finding only dengue but other arboviral diseases and finds ways for its prevention and control. In addition, addresses a policy priority as 95% of the country is at risk of arbovirus.

		It is directly relevant in 95% of Colombia and particularly the state of Cundinamarca that have the greatest dengue incidence and burden of infection.
Relative advantage	1. Does the innovation have relative advantage over existing practices? 2. Is it more cost-effective than existing practices or alternatives?	Container covers are a one-time component intervention, resulting in lifelong protection of productive containers resulting in lower vector indices. Modelling, costing, and impact studies indicate that is costly but cost effective. The potential impact is greater than local control program interventions.
Easy to install and understand	1. What degree of change from current norms, practices, and levels of resources is implied in the innovation? 2. What is the level of technical sophistication needed to introduce the innovation? 3. Are major additional human or financial resources and commodities needed to introduce the innovation?	Container lids are a challenging component of the intervention to implement since it requires some degree of skills to customise each lid to the different shapes of tanks (Figures of covers can be seen in Appendix C2) Insufficient procurement of insecticide materials and aluminium for construction the covers. The number of covers necessary to achieve higher impact on dengue transmission is at

		least to cover 70% of all households, with consequently potential implications for human resources, facilities, and supplies.
Compatible	1. Is the innovation compatible with current values or services of the user organisation? 2. Will it be difficult to maintain the basic values of the innovation as expansion proceeds? 3. Will changes in logistics need to be made to accommodate the innovation? 4. Which components will need local adaptation to be relevant for changes in local context?	The prevention and control of *Aedes*-transmitted diseases are a regional, national and local policy priorities. Resource allocation is needed for expansion and for accommodation of the innovation in the local policy.
Testable	1. Can the user organisation test the innovation in stages without fully adopting it?	A pilot project was conducted previously (24,30) and during this pilot the intervention was tailored to the local context. This pilot provided information for the present subsequent scale-up under evaluation.

* Key questions to be answered for each of the attributes.

6.4.2 The Environment

In this section, the contextual factors that build the conditions in which the intervention took place are evidenced. Economic, political and dengue disease are the main contextual factors.

a. Economic context

Girardot is mainly defined as a touristic port that has historically received migrant populations from various regions of the country. Since the late 19th and early 20th centuries, Girardot has been configured as a water and land port that connects the north with the south regions of the country through the road and the river port of the Magdalena River (31). These projects failed due to economic circumstances and bad administrations, which culminated in the closing of the railroad operation in 1970 (32). From this moment on, Girardot was configured from its development plans as a tourist centre (33).

Inquiring with residents about the importance and effect of Girardot's delimitation on tourism, some elements were observed, such as the prioritization of tourists over residents, which has increased informal commerce, service establishments (recreational places, restaurants, and discotheques) and popular festivals.

> "*From the beginning Girardot is a population with a diverse culture because of all the migration, that makes that there is no identity. (...) and then Girardot became a floating population of people who come here only on weekends*" (Community leader 2017).

Another element that was underlined in the interviews is that during the Chikungunya epidemics in 2015 tourism decreased, along with hotel occupancy and all related services to this economic activity. This disease burden perceived in economic commercial activities is identified as an element that encourages the association and joint action collaboration of different actors and sectors beyond health.

> *"The committee, as such, is a space for all of us who are active in the municipality to work together to alleviate the burden of the Aedes aegypti, which attacks us particularly hard since we are a tourist destination. Some visitors do not return because they became ill while on vacation, and the publicity doesn't help either"* (Multisectoral Committee member, 2017).

b. Political context

Historically, several corruption events have been reported since the adjudications for the construction and operation of the railroad in Girardot (32). Since 1988, mayors of cites have been elected, therefore decentralization of cities that give autonomy to local administration, has facilitated political negotiations of votes and jobs in the local, state and national bureaucracies, resulting in a high turnover at all levels from Health Secretariat to vector control program technicians. Most recently during the implementation of the intervention the former and current mayor underwent criminal proceedings by the Attorney General's Office for vote buying. In words of a stakeholder:

> *"The mayors or governors, or deputies negotiate their posts with this political capital; for example, a deputy says to the governor – "They gave me 10,000 - 15,000 votes and I became a deputy", and the governor responds: "clever, we will give X secretariat...", and the senator responds, "clever, I'll help you to get two of your people into the ministry if you help me get those votes for the next elections in the Senate". As a result, this is how political capital is negotiated… and Colombian legislation is skewed and rife of with ignorance"* (Key actor, 2017).

As a result, these events produced high levels of turnover in the local government (i.e. of decision makers and participation of vector control staff in intervention activities) with a change of opinions and sometimes unclear decision-making powers in a decentralised administrative system (where the national, province and municipal level compete).

c. Disease context (Dengue a cyclic priority)

Dengue is considered important, but its prioritisation is cyclic according to the outbreak of different epidemics and the emergence of new viruses. It has been reported to be perceived as a transitory disease.

> *"People think that it is something seasonal, a disease of the moment like a flu, people don't think it's important, they think that it's a fad and that's it"* (Community leader, 2017).

Its prioritisation is associated with a case of death and recently other *Aedes*- borne diseases have changed the way they are perceived given the Chikungunya (2014) and Zika epidemics (2015-2016), adding a greater complexity regarding the sequelae and chronicity that these viruses present.

> *"What is dengue for you? Well, it is a terrible and a dangerous disease, that causes inflammation and eventually death. Dengue fever is a haemorrhagic disease caused by the dengue virus. They say it is transmitted by a mosquito. And what about Chikungunya? That gave us all, it hurts the joints a lot, and you may present many sequelae" (Householder, 2017).*

6.4.3 The resource team

The leading role in the management of the scaling-up process was mainly completed by the research team. The research team is mainly composed of researchers from Fundación Santa Fe de Bogotá and UNAD. They led meetings, proposed actions to scale up "Girardot *Aedes-Free*" intervention, and coordinated training, field activities and resource mobilisation. These dynamic roles of the Fundación Santa Fe de Bogotá (Research team) were identified in the interviews. It also highlights the tools and support with which this institution contributed, based on the articulation with local and national entities.

"As is the case of the Fundación Santa Fe de Bogota, we know that it has been a strategic partner in this research task, based on this research the municipality has been able to detect the different factors and the different zones where these diseases may be incubating in the municipality. These partners, these allies that help us to investigate (of course we do not have the qualified personnel that performs that task), has been a fundamental tool for us to complement other vector actions proposed by the state and municipal level for the control of these tropical diseases" (Decision maker, 2017).

The research team promoted the inclusion of different actors and institutions in the promotion and facilitation of the "Girardot *Aedes-Free"* intervention to widen the resource team. A multisectoral and intersectoral committee (MSC) was built and approved based on a municipal agreement led by the Health Secretariat. This committee involved different public and private organisations including education, transit, social development secretaries, health services, churches, local academia, public schools, and public services sectors, with the intention to support the scaling-up process through their diverse skills in advocacy, resource mobilisation, monitoring and evaluation and training capacity.

The MSC is valued by key stakeholders and decision-makers, who report possible changes in the medium and long term, impacting the VBD problem in the municipality.

"These committees are important because they allow us to link the different forces of the city to support the implementation of the Integrated dengue strategy, to support programmes such as Girardot Aedes-Free, they are participatory spaces where commitments and bridges between the public and private sectors can be generated and built. The main space for vector borne diseases has been generated by the Fundación Santa Fe de Bogotá, which in recent years has led an intersectoral working group where the health sector, trade unions, the education sector of the municipality and other important actors are involved" (Multisectoral Committee member, 2017).

It can be identified that participation of different actors has been key to scaling-up, as well as its promotion in the national vector control guidelines such as the Integrated Management Strategy for vector borne diseases (IMS).

"At the specific level of the municipalities, I think it has been very important that these groups have been empowered, not only in the health sector but also in other sectors, to make these public health events visible as a priority. I believe that we have already achieved to have a background and a much more orderly articulation by the "EGI" (Estrategia de Gestion Integrada in Spanish, IMS in English) to develop these activities in the face of an event such as dengue" (Decision maker, 2016).

Multi and intersectoral action, as the starting point of vertical action for scaling up, was identified as the axis that articulates participation and action, based on the prioritisation and co-responsibility of different actors.

"The role of community leaders should be that of greater responsibility, to be that overseer within their community, to ensure that policies are concrete, and that people become aware and that their culture matures, their tendency towards good habits and good practices. Let it be a civic culture, the issue of being better citizens" (Decision maker, 2017).

Chapter 7 will describe in detail how the coalition was built and how it worked together to facilitate the scaling-up and implementation process of the intervention.

6.4.4 The user organisation

In Colombia, vector control is delivered by vertical and limited vector control programmes coordinated by state or municipal health secretaries (34). After the decentralisation process that took place in the 1980s, municipalities in Colombia were classified into six categories according to their institutional capacity and financial and administrative autonomy and this defined their local decision making over health and education decisions. Girardot, is currently category one, meaning there is a high-level financial and administrative autonomy to carry out public health and vector control activities.

The Health Secretariat proposed the adoption and implementation of the innovation at scale on the remaining two areas referred in Figure 3.1 in Chapter 3 (Sectors 3 and 4). However, it was evidenced that the Health Secretariat played a passive role in leading the institutionalisation of the intervention. After all the user organisation, due to political situation did not support the scaling up as the mayor had offered. The mayor offered that he might order by decree that all new residential constructions (houses, apartments), should have screens on windows but because he was removed for several month, political commitment did not remain.

Furthermore, the vector control programme is a structured programme with a fixed methodology and surveillance vector practice centered on documenting the presence and absence of larva, with limited funding, and a declining (technical and management levels) and lack of commitment among the vector control officers. Working with vector control officers was based on decisions by the local authorities as well as willingness and ability to collaborate in a new control programme that included monitoring by new vector surveillance methodologies (i.e. Pupae demographic surveys). Although these group of officers were trained in the new methodologies there was no evidence that they adopted these methodologies in their routine vector control activities during the study conduction.

6.4.5 The scaling-up strategy

The study protocol and monitoring study highlights the plan developed to deliver the intervention at scale. It includes the actions proposed by the research team to include "Girardot *Aedes-Free"* into local policies and local vector control programmes and identifies how the user organisation and other actors from the resource team responded. Table 6.3 outlines the strategic choices related to the type of scaling-up in dissemination and advocacy, organisational processes, costs, resource mobilisation, monitoring and evaluation.

Table 6.3. Strategic choices identified

Strategic choice area	Choices identified that were decided
Type of Scaling up	Horizontal: expansion/replication of the intervention to cover 4 sectors (10,000 households and public spaces) Vertical: institutionalisation of the intervention through intersectoral collaboration by a decree from the municipality mayor
Dissemination and advocacy	Communication and promotion of the intervention through community participation and mobilisation and intersectoral committee meetings. Communication tools: policy brief, brochures, mass media, Facebook, publications of results in scientific journals, policy dialogues with Ministry of Health (MoH) and state authorities during Zika epidemics, technical assistance and training to vector control programme technicians, technical assistance in research for education sector (Teacher's research committee, public schools and local universities)
Organizational process	Centralised gradual horizontal scaling up through research team and other local actors (community leaders, high school students) and sectors (members of multisectoral committee (see Chapter 7 for detailed description) and local enterprises (dress makers and cover manufacturers): bottom-up approach. Participatory process building coalitions under an multisectoral committee and local community members.
Costs and resource mobilisation	Costs and cost effectiveness were assessed by the economists of the research team as a tool for resource mobilisation at national and local government.

	Resource allocation was mainly driven by donors from different national governmental, non-governmental and international institutions: Colciencias, IDRC and TDR: budget for conducting the research project MoH: donated 1000 Insecticide treated nets No local health control programme budgetary allocation was identified, scarce participation of vector control technicians in field activities although they were trained in different technical aspects of VBDs.
Monitoring and evaluation	Monitoring and evaluation were mainly led by the resource team. Assessment of outcomes and impact: -Cost effectiveness assessment by the research team (35) -Impact assessment on dengue cases and vector density through field studies and analysis of local health surveillance data (Chapters 4 and 5). -Initial assessment of scaling-up process from research perspective in comparison with other ongoing vector control scaling interventions in Latin America (36).

6.4.6 Implementation process (Fidelity and mechanisms)

Horizontal and vertical scaling-up of the "Girardot *Aedes-Free" intervention* was planned and conducted during July 2015 and September 2017. The intervention was replicated in two (Sectors 1 and 2) of the four sectors planned (see Figure 3.1 in Chapter 3). It was not institutionalised in the vector borne diseases programme and legal local framework of Girardot, but a multisectoral steering committee for the prevention and control of vector-borne diseases was established, which will be described in Chapter 7. An analysis of the implementation of the intervention components revealed that most of the components were faithfully implemented, although the monitoring and evaluation of the actions were expected to be led by the user organisation (Health Secretariat vector control programme). Vector control staff participation within the implementation at scale of the intervention was possible during the initial phases and depended on the decision of the health secretariat administration. Once the scaling-up initiative had started, a new local administration came into being, which was responsible for appointing vector control staff and organising the activities. While the new administration settled, it was not possible to work with sufficiently qualified staff in the scaling-up activity so the research team had to lead the implementation, monitoring, and evaluation of all intervention components. Several meetings with the new municipal administration helped to socialise the project and consolidate the project in a joint effort for the scaling-up process.

Participant responsiveness

The interviews revealed that household actions were the principal component of the intervention visualised by the actors. When asked about what the intervention consisted of, community members and community leaders referred to the lids for covering large water tanks.

> *"... is a mesh that they place on the tanks to control the production or reproduction of mosquitoes, someone would arrive, conduct a survey and two hours later the staff came and do the work. It was according to the size of each tank, not specific measurements, but according to the size of each, they will work on the nets for the tanks" (Community member, 2017)*

a. General perception

The semi-structured interviews, as well as follow-up questionnaires, reported comparable results regarding participant perceptions about the intervention that turned around general perceptions of the intervention's delivery and installation, characteristics, quality, acceptance, and use of lids.

The majority of interviewed community members (95%, n=23) for whom lids for water tanks were installed, reported the intervention as "good". Likewise, most members surveyed during follow-up (93%

n= 1085), were willing to recommend the covers to others. The main perceptions about the usefulness of the lids were linked to the effect: covers reduce mosquito larvae in water tanks, stop mosquitoes from entering to lay eggs, and prevent the water from getting dirty. Likewise, 63% (729/1163) of the household members surveyed responded that they perceived fewer mosquitoes' larvae or pupae in water tanks covered by the lids.

In addition, changes in mosquito control actions were identified. Some 50% (n=12) of participants interviewed reported that their mosquito control practices had changed since the covers were installed. This change was stated in terms of suspending the use of chlorine tablets in water tanks and offering "peace of mind" in having water reservoirs fuller since mosquitoes will not reproduce. People who had not modified their practices argued that fumigation eliminated other insects such as cockroaches and ticks. Those who continued to use chlorine pills in water tanks said they did it to have double protection. The use of chlorine tablets in water tanks is a common practice in Girardot to reduce mosquito larvae and pupae and keep the water "clean". The latter point is supported by the data from follow-up surveys. Here, only 8% (n=92/1163) of survey respondents reported that they had decrease their purchases in insecticides or larvicides since the installation of covers.

b. Delivery and installation

92 % (n=1,071) of surveyed respondents reported that they were satisfied with the delivery of covers (See Table 4.2 in Chapter 4).

The installation of the lids was reported as fast and straightforward, and the project's staff were described as "friendly" and "a great group of workers". Problems reported during the installation included the dirtiness and unclean cuts left, which could be dangerous when using the covers. The field research staff agreed with the household members and argued that, in some cases, the need to make more covers compromised the quality and cleanliness of the installation work.

> *"……I think that quantity was the most important thing, not quality, and I think that in a project like this, quality is the most important thing. Because it is a research project, it needs to last, …. Here you also need quantity, so quality and quantity need to work hand in hand, quality and quantity can be done, you can't only focus on quantity because, if it's quantity, the person who is doing the covers is going to win more money, and they are going to lose because they are damaging the project, so to speak, because in many households people say that, they come in a hurry and they don't do things well" (Project field staff, 2017).*

c. Characteristics of water container covers

Several characteristics of the covers were identified. The practicality of covers, understood from its use and design, was reported by the participants interviewed. Community leaders and the community in general highlighted the slide and hinge mechanism for its innovation and easiness of use. They also valued the custom-made work in each water reservoir, based on the measurements and the elaboration of each cover specifically for each water tank, showing great results and complexity (Appendix C2: Images A to I. Types of water containers lids of Chapter 3).

> "*It is a new mechanism, it can be covered and uncovered very easily" (Householder, 2017).*

Aluminium as the frame material was considered an advantage of the lid given its low weight. Additionally, it was reported to fulfil an aesthetic function as it "beautifies" the water reservoirs. It was identified that the lid is part of a project that is making the problem of dengue and Chikungunya visible, which is not a priority for the municipality's authorities, leaders, and residents.

> *"It is a problem to which no attention is paid" (Community leader, 2017).*

The quality of the covers materials was reported as high, with 82% (n= 957) reporting that the quality of material was good and only 24% (n= 279) recommending changes (Table 4.2 Chapter 4).

The shortcomings identified by residents and community leaders were primarily related to the insecticide net. It was identified as being thin and with a soft material, which was unsteady and became loose from the aluminium frame, being of poor quality because "it breaks". Participants also reported the poor quality of hinges, which in some cases broke.

When discussing these perceptions with the project staff, it was identified that the net was very fragile and could easily break or detach from the frame for several reasons (inadequate quality of materials, inadequate use, inadequate installation).

> *"… in some cases, one can obviously say that it was due to manipulation by householders, in other cases we found that it was the material, we found damaged and loose screws…. The net was installed very tight that opening and closing the cover caused them to come loose…" (Project field staff) .*

> *"…, among the disadvantages of the covers, householders complaint about the awing of the net, we put them up ourselves, we help to attach the net to the frame, but the net is very, very soft, and it breaks with nothing, by just looking at it, it falls off. (Project field staff, 2017)*

They also confirmed the poor quality of hinges in the field and changed the supplier. Furthermore, at the time of follow-up, the majority of lids that were not being used or were damaged were due to misuse, such as placing heavy objects on top of nets. Some people claimed that animals such as cats would sit on the covers, breaking, loosening, and weakening the nets. This was validated by the research field staff members that saw this event during field supervision.

> *"It was the neighbour's cat, and we saw it, … we went to look at the mesh, and it was loose, and the mesh could be fixed, so one said, ok the cat theory can be true. Yes, because we went into two houses and householders from both houses gave the same theory, …, they were next door to each other and there was a cat..." (Project field staff, 2017)*

d. Acceptance

When asked what elements facilitated the acceptability of covers, the most reported characteristic was that it had no cost, which community leaders and the community valued. The reason for refusing to accept the covers was a fear that their price would be charged on utility bills. In two cases, the delivery of the lids was associated with political campaigns and social aid programmes of the mayor's office. Regarding this point, 29% (n=7) of participants identified the Fundación Santa Fe de Bogotá as the executor institution. They also mentioned the Secretariat of Health, the National Open and Distance University (UNAD), the government of Cundinamarca, and the Ministry of Health.

> *"Because is it free, now nobody gives anything for free" (Householder, 2017).*

Accessibility of households was possible due to the process of working together with the presidents of the community action boards. In Colombia community action boards are civic, social, non-profit and solidarity-based organizations, formed by citizens belonging to a community, neighbourhood, group, or sector of each municipality, locality or district in the country, with legal status and their own assets. They are autonomously organized with the purpose of promoting an integral and sustainable development built from the exercise of participatory democracy in the management of community development.

Likewise, working with local suppliers, recognised local personnel and students improved the reception of the community towards the intervention and the dissemination of the information. In addition, making the lids available in the homes, having continuous presence in the neighbourhoods, and carrying out monitoring activities raised interest among other community members and household members. This element of natural dissemination of information increased the acceptability of residents based on better knowledge and materialisation of the intervention.

> *"As people see that we are from here, they do not generate so much resistance. It is easy to know who is from here. There are also many casual friends. People see that we go to a house, and then we go to another to install the lids, and that reduces distrust" (Lids implementer, 2017).*

A limiting factor for acceptability included the lack of risk perception and the importance of the project.

"Families believe that they are immune to these diseases. People think that because they are strong, it does not affect them" (Householder, 2017).

It is argued that people stopped using the covers because they did not perceive the added value as the installation of lids did not require their work. For this reason, they did not repair the covers. Besides, there was a dilemma in terms of either giving the lids for free or charging for them.

"People like everything given away, they don't appreciate it, and there is no sense of belonging" (Community leader, 2017).

"Why don't people take care of things? Because maybe it does not cost them. When thinks cost you, you take care of them (…), but if things are charged it is worse, people do not allow to install them" (Householder, 2017).

According to the perception of the project staff, there was a high level of acceptance of covers, which is a factor that influence continued use.

"What is the level of acceptance? It all depends on how well community members take care of the covers, as well as whether or not the cover was valued as good or bad (...) Based on the first follow-up, I believe that 80 percent of those who liked the covers will continue to take care of them, and in this way, this can be a sustainable intervention." (2017, Project Field Staff)

e. Use

Four out of 18 interviewed household members reported that the cover was damaged or was not being used at the time of the semi-structured interview. Likewise, satisfaction follow-up surveys reported that among the householders not using the covers at the moment of the survey (159), 76 % (121) of this was due to damage. The damage tended to be that the net had been broken or the frame had fallen. The more complex designed lids were associated with damage, particularly lids of large water tanks that were no longer in use. 3% (37) of respondents reported that they had repaired the cover (net repair: 21 and aluminium frame repair: 16).

Regarding the continued use of covers, householders discussed what they would repair the lid it became damaged. Both project staff and community leaders argued that there would be some cases in which the lid would not be repaired, as this generated a cost.

"People do not have money to repair or make new covers" (Householder, 2017).

However, 87% (n=1,012) of the surveyed household members reported that they were willing to pay for the lids if they were sold.

Another limitation for using the lids was "the lack of habit" of the household members, which was associated with not taking care of and not repairing them. It was evidenced that the information provided was insufficient to repair the covers and acquire the nets in case of damage. Therefore, the community suggested that a brochure should be delivered with information and places to consult in cases of damage or deterioration.

6.4.7 Barriers and facilitators

The barriers and facilitators for the scale up of "Girardot *Aedes-Free"* are summarized below by domains in Table 6.4.

Table 6.4. Facilitators and barriers for the expansion and institutionalisation of "Girardot *Aedes-Free*" intervention

Categories/Domains	Facilitators	Barriers
Environment (inner and outer context)	• International and national policy support • Dengue policy priority • Financing support (MoH, IDRC, TDR, Colciencias) • *Aedes* control in the era of emerging arboviruses • Prior work of resource team in the area	• Corruption • Political instability
Innovation characteristics	• Correct attributes • Evidence based (previous efficacy trial) • Participatory design (Ecohealth approach)	• No local sources for purchasing or acquiring insecticide treated nets • Insufficient quality of nets • Insufficient qualified manufactures
Resource team characteristics	• Leadership capacity • Well known scientific institution • High capacity for engaging stakeholders	• Insufficient outreach for knowledge transfer
User organisation characteristics	• Health secretariat finds the intervention acceptable	• Insufficient resources for further scaling

		• Weak monitoring and evaluation mechanisms • High rate of technical staff turnover • Insufficient leadership attributes
Scaling-up process	• Leadership of resource team for expansion and stakeholder engagement	• No incorporation of the • intervention in local policy • Lack of sustainability of intersectoral committee • Lack of financial planning
Participant responsiveness	• Community members and householders find ITM covers acceptable and useful	• Unavailability of resources to repair lids damaged.

6.5 Discussion

This study evaluated the scaling-up and implementation processes of a vector control intervention ("Girardot *Aedes-Free")* by analysing the identified facilitators and barriers identified. There is a growing literature on key factors influencing the scaling-up and implementation of health interventions in different settings particularly in the fields of maternal, reproductive health and nutrition (37,38), but scarce documentation is evident in vector-borne diseases and this is even more pronounced for dengue. This study makes its contribution by considering the role of each factor in the process of expanding and institutionalizing and intervention for the control and prevention of *Ae. aegypti* at a local level.

Innovation/Intervention characteristics

Specific **characteristics or attributes of an intervention** facilitates its scaling up. "Girardot *Aedes-Free*" intervention, arguably has five (credible, observable, relevant, relative advantage, and testable) of the seven attributes needed for a successful scaling-up process. For example, the initial phases of the intervention, a pilot study carried out in 2015 (39), demonstrated that the intervention was effective, as has been demonstrated in studies conducted in other countries through CRT (40,41). Furthermore, the pilot served as a deciding mechanism of what elements should be scaled up or adapted. The pilot study evaluated the coverage and uses attained of both the covers and curtains implemented. The analysis revealed that 29 weeks after curtains implementation the percentage of use decrease to 45% for several reasons (house decoration during Christmas, cleaning and change of household) (24). The later has been also been reported by Vanlerberghe, et al.(42) in Venezuela and Thailand (43,44) reporting that the effect (reduction in entomological indexes) depends on the coverage attained, and this declines rapidly over time. In addition the study in Thailand, reported that house designs were unsuitable for using ITNs (45). Moreover, the evaluation of the intervention in other areas under a quasi-experimental design (evidence from the real-world trial), reported in Chapters 4 and 5, suggests that the intervention is still effective in reducing vector density and dengue cases even though curtains were not included for the scaling-up phase.

Recently, Beets et al. (46) discussed the importance of pilot /feasibility studies as primary phase to optimise the identification of interventions that should be scaled-up. They argue that to guarantee that an investment in a bigger, more well-powered study is justified, considerable thinking and preparation are necessary to create "adequate" evidence. Smaller-scale experiments feed larger-scale trials. Starting small seems logical, but smaller studies come with major judgments that might affect the value of the evidence used to guide decisions about whether to move forward with a larger-scale study. The authors analyse that It's difficult to build enough data from smaller research to warrant larger-scale, decisive trials. The type and amount of evidence required to be regarded acceptable for any specific intervention is intrinsically diverse, ranging from interviews with persons of the target group to a small-scale randomized experiment that resembles the larger-scale study.

One of the challenging attributes of "Girardot *Aedes-Free"* intervention was its complex installation of lids. It is important for scaling-up interventions to propose technologies easy to install, understand. The diversity of household ground water containers posed challenge to implement mass installation of lids. As each household had a unique design and size of water containers, implemented lids had to be customized for each container.

Another limiting attribute of "Girardot *Aedes-Free"* intervention was its compatibility and need for additional planning. The intervention required resource allocation expansion and accommodation of the innovation in the local policy. Though multiple efforts were made to locally institutionalize the intervention through the health secretariat, the limited resources of the local budget for vector control in Girardot compromised its institutionalization. Insufficient resources (human, material and financial), logistics and supply chains were identified to meet the needs when expanding the intervention in other sectors, institutionalising, and maintaining it in the existing public health system. These constitute potential barriers for scaling up interventions , as described by a systematic literature review on factors influencing the scale up of public health intervention in low-middle income countries (47).

The intervention, specifically the environmental management component (covers for most productive breeding sites), required additional human, financial and material (aluminium and insecticide-treated nets) resources, not only to further expand the intervention but to allow its adoption by the user organisation that adopts it. Spicer et al. in 2014, reported that one important characteristic is the low cost of an intervention, other relevant characteristics include its importance, relevance, effectiveness, observable benefits, acceptability, simplicity, adaptability to different contexts and sustainability. He discusses that limited funds restrain the government's capacity to scale ideas, and implementers typically vie for attention: low-cost innovations have a better chance of being accepted by the government, especially if evidence of their costs can be shown. Implementers are caught between focusing financial and other resources on 'boutique projects' to impress their financiers, and generating non-complex, low-cost innovations, which are likely to include quality and scope compromises. Because of the need to meet core program objectives, if scaling up the intervention is not a stated deliverable, implementers are reluctant to devote resources to it. Indeed, it may be in their best interests for them to avoid putting future financing at risk by turning over innovations (48).

Environment

Medical Research Council process evaluation and ExpandNet frameworks both postulate that the **context (outer and inner)** and cultural relevance of an innovation are critical factors influencing the scaling-up of an innovation (3,17,49–51). It is worth nothing that, according to the findings, epidemics and the emergence of novel viruses (in this case, Chikungunya and Zika) are clear opportunities to form coalitions amongst diverse actors and institutions in order to manage a crisis and policy response. As stated by Horton in 2016:

> *"Epidemics change governments… Those leaders understand that their nation's political, economic, and social stability depends on health. This realisation has consequences. Laws are enacted to protect health. New investments are made into medical science (political progress depends on scientific progress). New institutions are created to channel the best scientific advice to decision makers" … Epidemics change the public conception of disease. Diseases are no longer seen as pathologies of the body. They also become pathologies of the environment"* (52).

Evidence states that the process of research and policy formation or decision making usually takes place separately, though there are specific moments for the actors of each process to interact and contribute together. Therefore, a moment of opportunity which can be defined as the conjunction between research and the formulation of public policy at specific times that need to be carefully identified (53). In the case of Girardot, both external and internal contexts are key. While the external context generates an enabling environment of political priority, the inner context must be aligned to add up to common achievements. Endemic diseases in their epidemic cycle (dengue) and emerging diseases (Chikungunya and Zika) resulted in the prioritisation of activities for the control and prevention of diseases transmitted by *Aedes aegypti*, given their economic impact on health services, tourism, and the epidemiological alert for Zika issued by the World Health Organization in 2015. The mobilisation of resources and personnel becomes a possibility and a facilitating factor for the inclusion of policies, in the case of "Girardot *Aedes-Free",* the formation of a multisectoral committee, given the identification of a perceived needs among both institutions and inhabitants.

The economic context additionally played a double role, as both as a facilitator and a barrier. Tourism as stated earlier is the focus of the economic activity and is affected by dengue outbreaks. Here, control over the cause becomes a priority and this is how this common issue that affects everyone becomes an element that mobilises actors and sectors. On the other hand, tourism can be seen as a limiting factor in terms of inhabitants identifying themselves as part of territorial identity (54,55). Garcia et al. in 2019 (56) evaluated the concept of territorial identity where "Girardot *Aedes-Free"* was implemented and concluded that the lack of belonging, caused by weak community relationships and political instability, has made the prevention and control of controlling vector-borne diseases more difficult.

The history of corruption occurring in the municipality of Girardot produced changes in the local administration, impacting the ways diverse programmes operated. In Colombia, majors are elected every four years, and a common type of corruption is clientelism (57). Each new major selects their working team according to their personal preferences. As a result, high levels of turnover in the local government occurs, new types of leaderships and political will that aligns with new policy priorities and financing are established by each administration, as they find their own ways of working affecting the possibility of adopting a new intervention. Several studies from Yamey et al. (58,59), Magham et al (60), Bulthuis et al. (47), Omino et al. (61), Ghiron et al (62), Dopson et al. (63) and Zomahourn (64) have identified and recognised the context as an important active factor influencing the scaling up of health interventions. Furthermore, it has been highlighted that the context is a social ingredient that evolves over time and attention must be paid when the shift in the environment may aid in aligning innovation adaption with organizational need and capacities. Recognition and capitalization on the variability of context and its influence on the sustainability and scale-up of innovation process must be addressed to guarantee that the innovation is viewed and perceived as credible, valuable, and feasible. The effectiveness of the process relies on the knowledge of the context, whether at the individual or as represented in institutional features such as governance, resources, incentives, accountability or norms (65).

User organisation

In addition, that the **user organisation** (Health Secretariat) underwent changes in leadership, there has been a constant lack of capacity and competency of the programmes that it leads and coordinates, affecting actions in vector control. It has been documented that vector control in Colombia as well in other Latin American countries is delivered by national and local vector control programmes. These programmes encounter several difficulties in their management and organisation, with an insufficient amount of funding and community involvement, a lack of personnel (operational staff) and technical expertise, and issues with monitoring and evaluation (66–70). Therefore, the adoption of new interventions must be designed to avoid encountering such barriers as much as possible. For introducing new interventions or to scale up a proved effective intervention in a frame of decentralized scenario, such as Colombia, the strategy should be to approach local authority to demonstrate the benefits of the intervention in terms of impact in reducing burden of disease and cost effectiveness of the intervention.

A systematic literature review conducted by Bulthuis et al. in 2020 (47) reported that the majority of the studies examining scaling-up health interventions have evidenced that, particularly at local level, weak governance, leadership and management capacity are persistent barriers, and as Spicer et al (48,71) argued this poses a dilemma if scaling-up efforts should be carried out within or outside existing government system. The study (48) revealed that working with local governmental systems may in one end limit the process due to delays, corruption, bureaucracy, poor infrastructure and information system, weak human resources or partial confidence of end-users, although other studies revealed that if the intervention is embedded in the local systems this enhances the scaling up (61,72) but if not, ownership of the intervention will be limited (73).

The political context in supporting the process of scaling-up an intervention is crucial, not only at a local level but also at the regional and national levels. Although there were some constraints presented during the implementation of *Aedes-Free* intervention the political context was favourable for the scaling-up of the intervention. The MoH (potential user organisation) supported the scaling-up of the intervention and helped to mobilise other political actors, mainly during Zika epidemic by promoting advocacy and donating ITMs.

Resource team

ExpandNet/WHO defines the **resource team** as the organisation or group of individuals that promotes and facilitates the scaling of an intervention, that can be officially designated and situated in the group as the user organisation that will adopt the intervention. The resource team can be constituted by several actors who may play a role in catalysing the intervention on a large scale, by either expanding the coverage or institutionalising it. Examples of these actors are: researchers, programmers, trainers, community providers, health advocates, policy makers, and intervention adopters (1,2,51).

The leading role of in the resource team was exercised by the research team (FSFB) that was characterised by having key attributes of a successful resource team (skills in advocacy, resource mobilization, management, time needed to devote demands), as proposed by ExpandNet guidelines (1,3). FSFB has the technical and scientific capacity, experience and is a well-recognized institution in the health sector in Colombia. These attributes have been reported in other experiences that applied the ExpandNet/WHO systematic approach (62). Particularly, it was evidenced that among the three lessons learned is the capacity of the members resource team to lead the scale-up an intervention. Authors discussed that when scale-up was intended to take place within government systems, it was vital that government have a prominent role in the resource team. Even when initiatives are backed by technical organizations, such leadership fosters government ownership of scale-up programs. It also avoids the program being regarded as a donor-led initiative, which can have a detrimental influence on local ownership, intervention institutionalization, and resource mobilization.

The case study evidenced that the research team made efforts to guide and promote the leadership of the local institution (user organization) to scale up and implement the intervention. However, building (providing the important technical support) leadership and other soft skills will require knowledge transference, funding, and time. So that local institutions have sufficient capacity and political will to continue with the scale up process in the absence of the research team. Additional research financing could not be secured, preventing that the research continued to provide critical technical assistance to the local, cross-sectoral resource teams who were driving the scaling-up process.

The research team led a bottom-up approach to scaling-up “Girardot *Aedes-Free*” intervention by involving different stakeholders through participatory mechanisms. Furthermore, Zomahoun et al. (64) discussed the six pitfalls to be anticipated when planning scale-up interventions. Among these pitfalls encountered there is the type of approach used to scaling-up: top-down or bottom-up. Both approaches, an hybrid approach (74), seem necessary for optimising the scaling-up; both approaches will encounter or will need the collaboration of a diverse range of actors that play different roles during the scaling-up process (implementers, users, communities and adopters). A bottom-up approach (75) usually involves the participation of different actors and sectors using participatory methodologies, and it will face a level of engagement that will be difficult to replicate in a larger scale. On the other hand, a top-down approach will probably have more financial support and be facilitated by the political will.

Scaling up strategy

The **scaling up strategy** as defined by the ExpandNet/WHO framework refers to the plans and actions required to establish an intervention in policies, programmes, and service delivery. It includes the actions used by the resource team during the process of scaling-up the intervention within a wider system and by the attitudes used by the user organisation when responding to the actions (1,3). Various models or frameworks and scaling experiences in health interventions argue that having and using a strategic plan for scaling-up an innovation is a critical factor that requires consideration as it influences the process as it allows the ability to make strategic choices regarding financial, human and technical resources, including training, monitoring and timing of actions in the scale up process (2,3,47,61,62,65,75–77).

The resource team considered a plan and during the process of scaling-up took strategic choices to advance towards success. It is important to emphasise the resources offered by the team in building coalitions between diverse actors and institutions belonging to different sectors. This was built as a principal axis that articulates participation and action on the prioritisation and co-responsibility of the members.

Community participation and transdisciplinary are pillars of the Ecohealth approach (78). These pillars highlight the contribution of research and action, thus increasing the impact of beneficiaries, where stakeholder involvement and community members increases the likelihood of finding and using new knowledge. Particularly transdisciplinary also known as transdisciplinary thinking uses approaches and viewpoints that cross traditional disciplinary boundaries. It demands the team members to systematically share roles transcend disciplinary borders (78, 79).

The process of involvement becomes crucial and in this sense in the participation of actors and the co-responsibility of actions (78,79). In this way, the articulation, participation and prioritisation of multisectoral spaces are documented as facilitating factors for the development and scaling-up an intervention, given the conjunction of the approach, national policies, the perceived need of local decision-makers and the participatory mechanisms that exist at the local level (47,61). Therefore, identifying ways of sustaining the participatory scenarios is crucial. Further barriers and facilitators of the multisectoral coalition are analysed in depth in Chapter 7. Promoting participatory and multi-intersectoral scenarios was a facilitating factor during the process of scaling-up "Girardot *Aedes-Free"* intervention. But additional efforts are needed to achieve vertical scaling-up and creating further sustainability.

Another important choice made during the scaling-up plan was the parallel assessment of impact and cost-effectiveness of the intervention (Chapters 4 and 5 discuss the impact in vector density and dengue reported cases).

Costs and economic analyses as a scaling-up condition have been covered in existing scalability frameworks and checklists (48,80–84) and constitutes a tool for decision making for optimal scale (85). Moreover, there are factors affecting the cost of scaling-up interventions that need to be addressed or considered as the costs of scaling up an intervention are unique to the type of intervention and the location in which it is implemented: geography (distances for supervising), infrastructural features, supply chains, availability and capacity of human resources (how may need extra supervision and assistance) (85).

The resource team conducted an economic evaluation that involved the comparison of *Aedes-Free* intervention with the vector local control programme in terms of both costs and consequences, and concluded that the intervention is potentially cost-effective (35). These results can be used by the user organization to examine issues related to efficiency and sustainability and to inform resource allocation decisions (86) .

Fidelity and mechanisms

The fidelity of an intervention implementation and the mechanism are two dimensions that are related to the effectiveness of an intervention and to the success of the scaling-up (19,87). Although "Girardot *Aedes-Free"* intervention was not fully implemented (by user organisations) and scaled-up (reaching four sectors) as intended, it achieved positive results in reducing *Ae. aegypti* density and therefore the amount of dengue reported cases, as discussed in Chapter 4 and 5. When analysing the fidelity of the intervention the component that underwent the greatest challenge in terms of adaptation was the implementation of monitoring and evaluation actions that needed to be conducted by user organization. Adaptation of an intervention can be defined in the framework of fidelity as changes made to the original design of an intervention by its implementers or users and are necessary for its effective implementation (18).

Although in the implementation of "Girardot *Aedes-Free"* efforts were made in terms of participatory and multistakeholder and sectoral actions (essential to develop user engagement and ownership), the majority of actions were led by the research team instead of the user organisation (as examined earlier) in order to continue with the proposed timeline of the project. This can be seen as a responsive adaptation in response to emerging contextual issues (political) that occurred during the implementation of the intervention (88). This form of adaptation may have occurred owing to the user organization's lack of leadership, intervention implementation competence, intrinsic motivation, financial incentives, and insufficient planning procedures.

Regarding mechanisms or moderating factors such as context, facilitation strategies have been covered and discussed previously. Another factor related to fidelity and proposed as a mechanism is

acceptability. Acceptability of the intervention by different actors and sectors can be considered one of the principal mechanisms that was associated with the positive results in effectiveness of "Girardot *Aedes-Free"*. Proctor et al. (89) identified acceptability as one of the outcomes of implementation (among adoption, appropriateness, costs, feasibility, fidelity, penetration and sustainability) required to achieve intervention effectiveness and defined it as the "perception among individuals, organizations and entities involved in implementation that a given treatment, service, practice, or innovation is agreeable or satisfactory".

The study found that in general the level of acceptability of "Girardot *Aedes-Free!* intervention for *Ae. aegypti* control among community members and other stakeholders of Girardot was high, with over 90% expressing acceptance (initial uptake) of ITM covers in their households. Other proxies measuring acceptability, such as satisfaction with delivery process, uptake, use, and willingness to pay were high. The levels of satisfaction with ITMs are similar to the findings reported by several studies (40,41,90–92) and the results from the previous efficacy trial (24), that evidences that the factors that influence the level of acceptability and use of the intervention were related to the non-cost, perception of being useful in reducing not only mosquitoes but other insects, aesthetic function and practicality of covers, with some constrains related to screen fragility, the installation process and the context described by Jones et al. (12) for insecticide treated window screens in Mexico.

The factor related to the fragility of the screen (net and hinge) poses a challenge in cover sustainability. Maintenance and repair will need attention in the long term, related to costs and ways of purchasing nets or other materials for developing the covers. The net material for lids was adapted from insecticide treated nets for curtains. As the material was not developed to be used for lids, the material did not perfectly adjust to the aluminium frame, thus eventually loosening. Different materials could be used as nets for the lids, to ensure long term proper fitting. Non-insecticide treated materials may pose a suitable option, as they are easily obtained by the community and frequent repairs could be more feasible.

In terms of non-cost factors, the perception of being effective in reducing not only mosquitoes but other insects, aesthetic functions and practicality are among the factors that influence the level of acceptability and use of the covers during the time frame of the study.

Although acceptance related to product attribute is an important factor, it does not assure a sustained use (93). According to Proctor et al (89) acceptability of health interventions is a dynamic process that evolves with time and user experience. This emphasizes that there are other critical factors that may influence acceptance and their change over time that need attention and assessment. For example, human behaviour that is much more complex and it plays a critical role in determining how long ITM remain effective (90). Toledo et al. (94) found that top–down replacement of faulty water storage containers –

while effective from a technocratic a priori standpoint – does not guarantee a persistent influence on entomological indicators without an associated behaviour modification approach.

6.6 Limitations

Some limitations in this study can be acknowledged. Firstly, this case study explored the experience of scaling and implementing an intervention at a local level, limiting the generalization of the findings. Secondly, the evaluation took place at one time point and the analysis were not validated with respondents. Continued follow-up will be essential to capture changes in the sustainability of the intervention and further scaling up.

6.7 Conclusion

The study demonstrated the learning achieved through the process of scaling and implementing the intervention and evidenced what can be achieved during the time horizon analysed (project horizon). Two years resulted in an initial scaling-up progress and therefore steps to ensure total ownership by the user organisation or organisations are needed. Two issues (related each to the other) is worth to mention. First for implementing and, therefore for scaling up, a public health intervention political will of the local authority is crucial, if the mayor of the municipality is not interested or is not a priority for his/her government, hardly to introduce a new intervention. The second issue is the governance, understood as, with its four elements, management and leadership, technical capacity, participation, and institutional structure.

The lessons learned in the implementation of the scaling-up of "Girardot *Aedes-Free"* intervention have implications in the planning of other vector-borne interventions, as well as in other health interventions in Colombia at a local level. Facilitators and barriers that are not specific to the intervention that influence the scaling up of "Girardot *Aedes-Free"* intervention are adequate resource allocation, leadership of the user organisation, political context, and engagement of stakeholders through participatory actions. It is important to point out that many authors such as Indig et al. (95), Milat et al. (76,84) and Barker et al. (77) have identified the pathways and factors for scaling-up interventions/programmes. Among the stages proposed there are: theoretical development of the intervention, efficacy testing of the intervention, real-world testing (field testing or replication), and dissemination at the population level, including adaptation. Furthermore, it is also likely that the use of participatory research and social-ecological theories during the phases are plausible factors. But it is not clear whether adherence to all or some of these issues results in major scaling-up or sustainability.

6.8 References

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Chapter 7 Study 4. Multisectoral collaboration in the context of "Girardot *Aedes-Free*" intervention

7.1 Outline

This chapter details Study 4, which assesses a multisectoral partnership action built in the frame of "Girardot *Aedes-Free*" intervention, to better understand what type of local-level joint action was developed and adopted examining the nature of the partnership, which actors were involved, how different actors/sectors interacted and how they were able to collaborate. In addition, this chapter evaluates the success of the partnership and identifies the strengths and limitations on the status of the coalition. As mentioned in Chapter 6, multisectoral collaboration action was built as the main strategy for scaling up the intervention.

7.2 Introduction

Successful scaling-up and sustainability of health interventions generally require the development of a multi-stakeholder partnership. Several international, national and local level action frameworks (1–4) call for promoting health through holistic, multi-, and intersectoral, multi-partnership, multilevel collaborations, and actions that encourage the participation of affected communities as well as action across inter-and intra-national frontiers and at all levels in multiple sectors. This dimension has received attention since 1978 from the well-known Alma Ata Declaration (5) as a strategy for improving health because it acknowledges that many factors that determine health in the population occur outside of the direct control of the health sector and consequently should be tackled through action within and between other sectors (such as education, local government, and tourism, among others). Most recently in 2011, the World Conference on Social Determinants on Health in Rio de Janeiro (6) stated the strategies for institutionalising intersectoral action and the Helsinki statement on Health in all Policies (HIAP) identified intersectoral action and healthy public policy as central elements for the promotion of health, the achievement of health equity, and the realisation of good health in general (2).

Intersectoral action or intersectoral collaboration can be defined as "*working with more than one sector of the society to take action on an area of shared interest to achieve better results than those obtained working in isolation. Sectors may include government departments (provinces) such as health, education, environment, non-profit organizations etc* (7,8) *".* Intersectoral action for health is defined as a "*recognized relationship between a part or parts of the health sector with part or parts of another sector that has been* *formed to take action on an issue to achieve health outcomes or intermediate health outcomes in a way that is more effective, efficient or sustainable than could be achieved by the health sector acting alone"* (7,8).

Several international, national and local level action frameworks discuss the importance of intersectoral multi-partnership collaboration that encourage the participation of affected communities, as well as actions across sectors, as a primary pillar of action to reduce dengue and other vector borne diseases (9–16). The frameworks base their assumptions on the following considerations: the epidemiology of Vector-Borne Diseases (VBD) that involves agents (viruses, parasites), hosts (primary, intermediate), vectors (mosquitoes), environmental, biological and social factors (17), the growing expansion of VBD across the globe and the complexity of and inter-relationships between drivers of VBD, meaning that the control and prevention of these diseases needs to be tackled by different sectors, not only the health sector alone (11). In particular, WHO recommends implementing the Integrated Vector Management (IVM) framework for the prevention and control of VBD. One of the key elements for the successful implementation of IVM is collaboration among actors and sectors through the optimal use of resources, monitoring and decision-making. Challenges are well documented. What requires to be well documented is how to implement successfully the multisectoral approach. As a result, the WHO Special Programme for Research and Training in Tropical Diseases (16), focused special attention to it, commissioning several systematic reviews (18,19) related to the multisectoral approach for the prevention and control of VBDs. These reviews identified knowledge gaps, conceptual frameworks and essential elements of successful multisectoral and intersectoral collaborations: governance, leadership, context (political support priority), common beneficial relationships, accountability, training, tools and capacity development, infrastructure (financial and human resources), coordination and integrating mechanism, partnering and social mobilization or community empowerment.

"Girardot *Aedes*-Free" intervention, as described in Chapter 3, is a complex intervention that aimed to reduce *Ae. aegypti* indexes and dengue reported cases. One of the main strategies, towards scaling up the intervention and lasting impact on dengue incidence reduction, was to build a coalition across sectors in which stakeholders in health and other local sectors, such as education, transportation, and tourism, participate. To better understand the multisectoral action partnership from a local viewpoint, this case study will examine and discuss how it was started, which sectors were crucial, how it functioned, how it was sustained, and what lessons were learnt.

7.3 Methods

7.3.1 Study design and data collection techniques

A case study using mixed data methods (20) was conducted to identify and assess the factors shaping a multisectoral partnership in a local context. Quantitative and qualitative data from the study documents were analysed (Table 7.1).

Table 7.1. Study documents and type of data analysed

Type of data	Study document	Description
Quantitative	Victorian Partnership Analysis Tool (VPAT) designed by the Victorian Health Promotion Foundation (21). Applied to 13 members of the Multisectoral Action Committee (MAC) participating in the last meeting documented in 2017	This tool is intended to assist organisations working in partnership to assess and monitor the effectiveness of their collaboration. The survey consisted of a checklist divided in seven domains 1. Determining the need for the partnership, 2. Choosing partners, 3. Making sure partnerships work, 4. Planning collaborative action, 5. Implementing collaborative action, 6. Minimising the barriers to partnerships and 7. Reflecting on and continuing the partnership. For each domain items were rated by the respondent members of the MAC) on a scale from 0 to 4, 0 indicating strong disagreement with the statement and 4 indicating strong agreement (Appendix G1).
Quantitative	Participation survey	The survey evaluated participation of sectors (represented by institutions and actors) in terms of: 1. Perceived participation of actors (evaluated on a scale from 1 to 5, 1 indicating null participation to 5 indicating active participation), 2. Activities carried out: (the committee member has carried out activities in the frame of the MAC: yes, no), and 3. Adequate representation and/or delegation: (yes or no) (Appendix G2).
Qualitative	10 minutes of the MAC	Minutes contained information that allowed the characterization of the functioning of the committee, the identification of the sectors participating in sessions, and activities planned and performed during the scaling up and implementation of *Aedes-Free* intervention study.
Qualitative	Audios of semi-structured interviews to 11 members of the MAC	Based on the VPAT responses, an interview guide was developed (Appendix G3) by the research team, which enabled in-depth exploration of the factors

Interviews lasted from 20 to 84 minutes.	pertaining to the partnership, including specific plans, priorisation of actions, types of activities carried out, management, outcomes, and specific recommendations for enhancing collaboration and/or sustainability. It was evidenced that all members of the multisectoral intersectoral committee, identified from the Municipal Council agreement (19 members identified), were contacted for the semi-structured interview. Eleven active members of the committee from 10 institutions were interviewed (between December 12, 2017 and January 18, 2018. These institutions were: Veesagir (citizen oversight) (n= 2), Ser Ambiental SA ESP (public sanitation services: solid waste) (n= 1), Secretariat of Health (n =1), Secretariat of Education (n = 1), Planning Office (n= 1), Asojuntas Girardot (Municipal association of community action boards) (n = 1), Municipal Institute of tourism, culture and promotion (n= 1), Land transportation terminal (n = 1), Fundación Santa Fe de Bogotá-FSFB (Health services and research Institution) (n = 1) and National Open and Distance University (Universidad Nacional Abierta y a Distancia- UNAD) (n = 1).

7.3.2 Data management and analysis

a. Quantitative data

Information from VPAT and perceived participation was included in a spreadsheet in CVS format and analysed in Microsoft Excel (22). Frequency and percentages were calculated. Scores per domains from the VPAT were calculated. Then an overall score was derived to indicate the overall strength and functioning of the partnership. The overall score was classified in three categories each, with each indicating the level of partnership. Higher scores indicated greater agreement with the VPAT items per domains. The VAPT suggest the following categories of partnership level:

1. 0 - 43: The whole idea of a partnership should be rigorously questioned,
2. 44 - 86: The partnership is moving in the right direction but it will need more attention if it is going to be really successful, and
3. 87-128: A partnership based on genuine collaboration has been established. The challenge is to maintain its impetus and build on the current success

b. Qualitative data

Audio recordings (in Spanish) from the interviews were transcribed and imported into the NVivo software (NVivo qualitative data analysis software; QSR International Pty Ltd. Version 12, 2018) to assist with data management and analysis. Documents and interview transcripts were read carefully and constant comparison with study objectives and categories was maintained. For analysis, key themes were identified and organised into codes given the categories of analysis. Categories and their components of analysis are those related to the features influencing (enabling or hindering) a successful collaborative action proposed by Herdiana et al. (18), the WHO multisectoral approaches guidance document (16) and derived from the VPAT tool: need of partnership, actors and sectors, participation of actors, management partnership and sustainability of partnership (Table 7.2).

Table 7.2. Definition of categories of multisectoral collaboration

Category	Definition	Components or Subcategories
Need partnership	Establishment of a clear purpose, objectives, and perceived benefits of the partnership Shared vision	Context
Actors and sectors	Types and variety of actors and sectors involved. Activities implemented Representation of actors	Roles per sector and actors Interests Willingness Skills Commitment Relationship Pre-existing collaborations
Participation	Participation of actors	Participatory approach used Pre-existing organisations Perceived participation
Management	Definition and implementation of actions by sectors Tools Resources Leadership Working group	Communication and administrative system
Sustainability	Factors that influence the continuation of the partnership over time	Actions for sustainability

In addition, the framework of intersectoral action in VBD established by Herdiana et al (11) was utilized to characterize the stakeholders engaged, their responsibilities, and contributions in the multisectoral collaboration. This framework depicts the following key components: strategic roles, activities, sectors involved, enabling roles, contribution, and scope of collaboration. Strategic roles are categorised in: (1) Prevent or minimize risk, (2) Provide early diagnosis and treatment, (3) Provide commitment, and (4) conduct monitoring and evaluation. Each one corresponds to a specific type of action. Actors are divided into two mayor categories (governmental and non-governmental) with a number of enabling roles or contributions indicated, including technical assistance, leadership and coordination, resource provision and facilitating access to groups or organisations of services or facilities that work in various collaboration contexts (local, national, regional or international).

Quantitative and qualitative information was analysed jointly, thus providing triangulation for the categories of the survey and the responses driven from the interviews.

7.4 Results

The establishment of the multisectoral partnership for the prevention and control of vector borne diseases in Girardot began on July 22 -23 2015, through workshops promoted by the research team for the definition of goals, actions, and participants. During the two-day workshop, 33 people from nine sectors and 21 institutions from government bodies and to non-governmental organisations participated. Although, twelve actors were considered as members to represent the sectors involved and three to coordinate the partnership (two non-governmental bodies and one governmental body). The sectors most represented was education (33.33%, seven institutions), followed by health (22.72%, five institutions) and local government (14.28%, three institutions). In 2015, four additional meetings were carried out where follow-up of actions and development of the action plan for 2016 were discussed. On average during 2015, 21 actors and six sectors participated (Table 7.3).

In 2016, five meetings were conducted and the formalization of the partnership was established as the "Intersectoral action committee for the prevention and control of Vector Borne Diseases (VBD)" by . an agreement of the Municipal Council on December 6, 2016. During this period the mean number of sectors participating in each meeting was four with a mean number of actors of 19 per meeting. Almost equal number of governmental (2) and non-governmental bodies (2.2) were recognized (Table 7.3). The principal sector that participated was education followed by health.

On February 24, 2017, the by-laws of the committee were created, the line of actions were defined and the following aim was established: "*to provide support for the implementation of the IMS for VBD and other essential strategies for the prevention, promotion and control of VBD in Girardot*"

Table 7.3. Number of sectors, institutions, and actors of the multisectoral collaboration per year

Year	Month	Number of sectors	Number of institutions	Governmental body	Non-Governmental body	Number of participating members	Number of coordinating institutions
2015	July	9	21	5	6	33	3
	August	6	9	3	5	18	1
	November	4	10	2	4	19	1
	December	5	7	2	4	13	1
	Mean	**6**	**11.75**	**3**	**4.75**	**20.75**	**1.5**
2016	March	4	6	3	1	11	1
	May	7	17	5	4	41	1
	August	6	15	4	3	27	1
	October	4	7	3	3	16	2
	December	7	8	5	3	23	2
	Mean	**4.2**	**9**	**3**	**2.2**	**19**	**1**
2017	February	9	21	4	7	26	1
	May	4	6	2	3	20	1
	September	8	10	4	4	22	2
	December	7	10	5	4	19	2
	Mean	**7**	**11.75**	**3.75**	**4.5**	**21.75**	**1.5**

During this year, four meetings were held. On average seven sectors were represent at each meeting. There were nearly equal numbers of governmental (4) and non-governmental bodies (5) representing different sectors. Education and health were the two principal sectors that participated. Figure 7.1, displays the timeline of activities evidenced during the course of the multisectoral action collaboration.

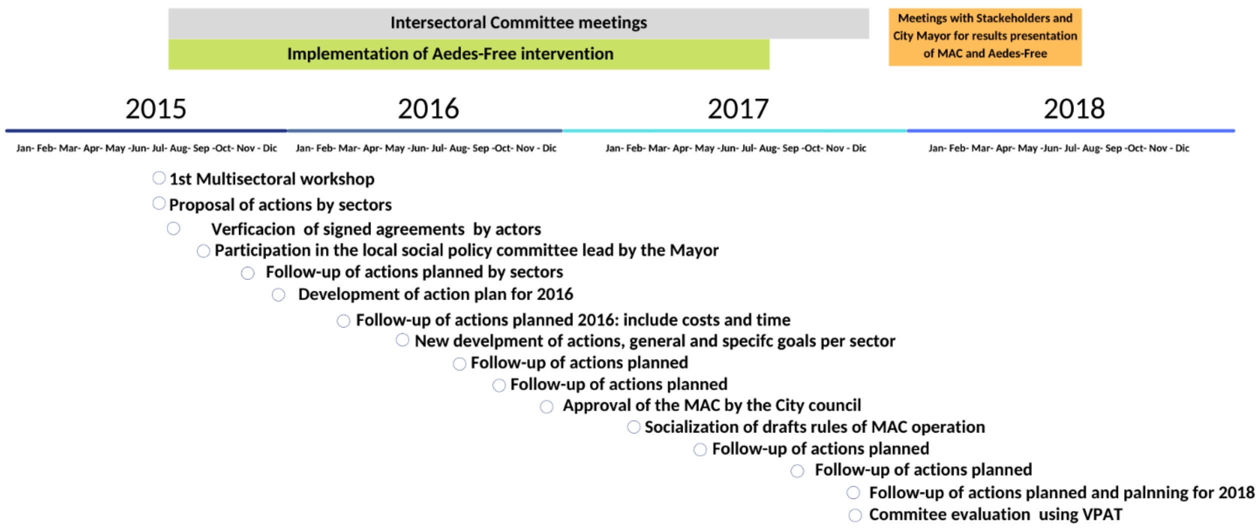

Figure 7.1. Timeline of the multisectoral action committee for the prevention and control of vector-borne diseases in Girardot

7.4.1 Features of successful collaboration

The VPAT was conducted on the 5th of December 2017, ten months after the MAC was approved by the municipality council. The survey was applied to 13 members of the committee, that represented nine (47%) of the 19-member institutions: Secretariat of Health, Secretariat of Education, Fundación Santa Fe de Bogota (FSFB), Municipal Institute of tourism, culture and promotion, culture and promotion, Land transportation terminal, Rotary Club, Veesagir (citizen oversight institution), UNAD and Serambiental (public sanitation services: solid waste). Table 7.4 presents the aggregated score results from the VPAT survey and Appendix G4, presents the detailed results of the survey. The total score was 89.77, which suggests that the partnership had been developed as a genuine collaboration. However, some of the key features rated better than others. For example, higher scores were seen in statements A (Determining the need for the partnership) and F (Minimising the barriers to partnerships), with percentages over 80%. Lower scores were seen in statement E (Implementing collaborative action), followed by D (Planning collaborative action) with percentages less than 65%.

Table 7.4. Key features of successful collaboration in the context of "Girardot *Aedes*-Free" intervention

Statements		Total score	Maximum score per statement and section	% of the total score per statement
A	Determining the need for the partnership	16.08	20	80.38
B	Choosing partners	11.38	16	71.15
C	Making sure partnerships work	15.85	24	79.23
D	Planning collaborative action	9.92	16	62.02
E	Implementing collaborative action	9.31	16	58.17
F	Minimising the barriers to partnerships	12.85	16	80.29
G	Reflecting on and continuing the partnership	14.62	20	73.08
Total		**89.77**	**128**	**71.88**

Need for the partnership

The need for partnership was identified by 92.30% of the members surveyed, but some problems were evidenced in terms of willingness to share ideas and having the resources to meet the objectives (69.23%). The interviews highlighted that the active members of the committee were those who understand the benefits and the objective of the committee; those with passive or null participation did not identify the objective nor the benefits of being part of the committee that is related to the assistance (either through delegation or representation).

The survey evidenced that actors identified a clear goal for the partnership (92.30%), and shared understanding and commitment to the goal (76.93%) (Appendix G4). Similarly, the in-depth interviews identified that fact the objective of the committee was known by the active members and was framed within national policies.

> *"The institutional policies from the Ministry of Health, there is indeed the motivation to create this type of committees, so that they top down to the municipalities, to achieve joint actions of different sectors, for this to be possible it is necessary the commitment of the committee members" (Committee member, 2017)*

The multisectoral partnership was initiated with the aim to provide support and monitoring of the implementation of "Girardot *Aedes-Free"* intervention and other strategies and policies necessary for the prevention, promotion and control of vector-borne diseases in Girardot. This partnership was institutionalised through the formation of a "Intersectoral action committee for the prevention and control of VBD". Its creation was framed under the Colombian Decennial Public Health Plan: 2012-2021), the Integrated Management Strategy for dengue and the call from national policy to carry out "sectoral and cross-sector interventions aimed at affecting social determinants and preventing, controlling or minimizing the risks that favour the appearance of events characterized by presenting endemic hotspots, variable transmission scenarios and secular, temporal, seasonal and cyclic patterns in risk populations " (23). A steering team was created to coordinate the multisectoral partnership and enhance commitment.

One element highlighted in the interviews was that during the Chikungunya epidemic in 2015, tourism, hotel occupancy and other services related to the main economic activity of the municipality declined. This economic burden of the disease, perceived in trade activities, is identified as an element that drove partnership and joint work.

> *"The committee, as such, is a space for all of us who are involved in the municipality to be able to mitigate the burden of Aedes aegypti, which has a particularly heavy impact on us because we are a recognised tourist destination. Some visitors/tourists do not return because they became ill while on vacation, and the awareness for not travelling to this endemic zone does not help either" (Committee member, 2017).*

Sectors, roles, and contributions (actions)

The actors who were part of the committee when VPAT was implemented (2017) represented different sectors and this is identified as a key element, because in this way the problem and solution are the responsibility of all sectors. Most actors agreed that the partnership shared common interests and approaches (76,92%) and that there was a history of joint work (76,92%).

The variety of actors is represented in 10 sectors. Table 7.5 provides a view of the principal stakeholders involved, their roles and contributions in the multisectoral partnership following the framework of Herdiana et al (18) described earlier in methods. In addition, Appendix G5 presents lines of actions and activities per institution and sector during 2015 and 2017.

Table 7.5. Sectors, strategic roles, and contributions of the local multisectoral committee for the scaling-up of "Girardot *Aedes*-Free" intervention

Sector	Actor	Type of sector	Strategic Roles/activities	Contributions
Health	Secretariat of health	Governmental	Environmental management Education: raise awareness and strengthen knowledge Surveillance of dengue cases	Access to groups Policy formulation Resources: human and epidemiological and entomological data
	Health promotion institutions	Non-Governmental	None	None
	Clinics and hospitals	Non-Governmental	Disease management	None
Transportation	Secretariat of Traffic Land transportation terminal	Governmental	Education: awareness to tourists	Access to groups Resources: communication materials
Tourism	Municipal Institute of tourism, culture and promotion	Governmental	Education: awareness to tourists	Access to groups Resources: communication materials
Education	Public Schools	Governmental	Education: awareness to community Social mobilisation	Access to groups Human resources

	Local Universities	Non-Governmental	Research and development	Leadership Technical assistance Capacity development Resources: human, finance
	Secretariat of Education	Governmental	Education	Access to groups
Research institutions	FSFB	Non-Governmental	Research and development Environmental management Monitoring and evaluation	Leadership Coordination Resources Technical assistance Capacity development
Civil society	Rotary club	Non-Governmental	Social mobilisation	Access to groups
	Citizen oversight institutions	Non-Governmental	Social mobilisation	Access to groups
	Association of Community actions boards	Non-Governmental	Social mobilisation	Access to groups
Public services	Water and Sanitation services	Governmental	Environmental management (waste collection)	Access to services
Religious	Christian church Diocese	Non-Governmental	Social mobilization	Access to community groups
Local government	Planning advisory office	Governmental	Policy: Legislation of the multisectoral committee	
Commerce	Chamber of commerce	Governmental	Stakeholder mobilisation	Access to groups and facilities Resources: human and data

It was identified by the VAPT that more than half of the committee members (53,85%) believed that the partners had the necessary skills for joint action and 69.23% argued that there were strategies in place to improve the skills of the actors through increasing the membership or workforce development

> *"I consider that the members and institutions that are in the agreement are the right ones, they are the ones that should lead the fight against Aedes aegypti. They have the skills, capacities, margin of action, competence, but it is all about will" (Committee member, 2017).*

In addition, will can be related to the assistance and performance of actions, in some cases apathy and lack of commitment of some actors were recognised because they did not identify the value of being part of the committee. In the VPAT survey it was identified that 53,84% of the members responded that the roles, responsibilities, and expectations were clearly defined.

Participation

Several members of the steering committee were also members of other committees and had a high workload that influenced the performance of actions and / or staff turnover, which could be counteracted by including or aligning the actions of the committee among their contractual activities.

> *"......those who attend recognise the added value of the committee." (...) Absenteeism occurs because the country is full of committees, and the officer who has to attend all of them is usually the same officer, who is usually a contractor with a specific contract objective, and those who have a permanent contract are few, so they have to attend all of them, it's a matter of structure" (Committee member, 2017).*

Furthermore, from the interviews, the most active entities were identified as those presented and involved with the disposition of the joint work. The following table presents how the interviewed committee members perceived the participation of each institution listed.

Table 7.6. Attendance and perceived participation of institutions in the multisectoral committee, 2017

Institutions	Attendance during 2017		Level of participation					Activities performed		Adequate representation and delegation	
	Number of meetings	Members per institution	1 Null	2 Null-Passive	3 Passive	4 Passive - Active	5 Active	Yes	No	Yes	No
			% (n=13)					% (n=13)		% (n=13)	
Local government institutions											
Municipality Hall	0	0	16,67	16,67	33,33	0	33,33	33,33	66,67	75	25
Secretariat of Health	4	7	0	0	16,67	8,33	75	81,82	18,18	81,82	18,18
Secretariat of Education	4	1	33,33	8,3	8,3	8,33	41,67	36,36	63,64	45,45	54,55
Secretariat of traffic and land transportation of Girardot *	1	1	54,55	9,09	0	9,09	27,27	45,45	54,55	36,36	63,64
Municipal Institute of tourism, culture, and promotion	1	1	9,09	0	45,45	27,27	18,18	54,55	45,45	63,64	36,36
Planning advisory office	2	2	45,45	18,18	36,36	0	0	9,09	90,91	9,09	90,91
Pro-development and security corporation	0	0	60	10	30	0		10	90	10	90
Chamber of commerce of Girardot	1	1	33,33	8,33	41,67	8,33	8,33	27,27	72,73	18,18	81,82
Land transportation terminal	2	2	0	0	9,09	18,18	72,73	90,91	9,09	90,9	9,09
Civil, social and community organizations											
Veesagir (citizen oversight)	4	8	9,09		54,55	9,09	27,27	40	60	50	50
Asojuntas	0	0	45,45	9,09	36,36		9,09	10	90	10	90
Community action board	0	0	50	20	30	0	0	10	90	0	100
Religious organizations											
Dioceses	1	1	50	16,67	33,33	0	0	0	100	0	100

Dioceses Association of Christian churches	1	1	50	16,67	33,33	0	0	0	100	0	100
Private Non - governmental institutions											
Girardot Rotary Club*	1	1	54,55	9,09	18,18	9,09	9,09	20	80	20	80
Fundación Santa Fe de Bogotá	4	5	0	0	0	0	100	100	0	100	0
Higher and technical education institutions											
Piloto University	1	1	63,64	9,09	27,27	0	0	10	90	10	90
National Open and Distance University	4	9	0	0	16,67	8,33	75	91,67	8,33	91,67	8,33
Uniminuto University	1	1	63,64	9,09	27,27	0	0	0	100	0	100
University of Cundinamarca	0	0	54,55	18,18	27,27	0	0	0	100	0	100
Health care providers and insurance companies											
Nueva Clínica San Sebastián - NCSS (Clinic)	1	1	72,73	9,09	18,18	0	0	0	100	0	100
Dumian (Hospital)	1	2	63,64	18,18	18,18	0	0	0	100	0	100
Famisanar	1	1	72,73	9,09	18,18	0	0	0	100	0	100
EPS Comparta (Insurance company)	1	1	72,73	9,09	18,18	0	0	0	100	0	100
EPS Sanitas (Insurance company)	1	1	72,73	9,09	18,18	0	0	0	100	0	100
Salud Vida (Insurance company)	1	2	72,73	9,09	18,18	0	0	0	100	0	100
Public service providers											
Acuagyr (water and sewerage public services)	1	1	8,33		25	16,67	50	100	0	90,91	9,09
Ser Ambiental SA ESP (public sanitation services)	2	2			9,09	9,09	81,82	100	0	100	0
Primary and secondary education institutions											
I.E Policarpa Salavarrieta	0	0	54,55	18,18	27,27	0	0	10	90	10	90
Instituto Kennedy	0	0	63,64	18,18	18,18	0	0	0	100	0	100
Instituto Educativo Atanasio Girardot – IETAG	1	1	63,64	18,18	18,18	0	0	0	100	0	100

* Institution that is not part of the Committee members described in the municipal decree.

The most active members of the committee, as perceived by the other members, were Fundación Santa Fe de Bogota (FSFB) (100%), Serambiental (81.82%), UNAD (75.00%), Secretariat of Health (75%) and Transport Terminal (72.73%). These are organizations that were recognized as those that operated activities and had adequate representation and delegation (high-level actors with decision-making authority) at the committee (Table 4). FSFB (research institution) was identified as the lead agency that coordinated funds, implementation and monitoring of the committee and *Aedes-Free* intervention.

Institutions perceived to have null or null-passive participation were Prodesarrollo, Universidad Piloto, Universidad de Cundinamarca, all municipality healthcare provider institutions, healthcare promoter companies and institutions of primary and secondary education. This is related to poor representation and delegation, low attendance at the committee meetings and no activities proposed or carried out.

> *"Neither heads of entities nor decision-makers assist, or information is not scaled-up or sent to the same delegates themselves, so there are people who assist as if to meet attendance, but they are not clear about the goals, objectives (...) there is a lack of awareness of the importance of the prevention and control of vector-borne diseases, as it is only considered a health issue."*

Delegation and representation are crucial elements to make the association work, based on a good representation, decisions are made, and members are active participants in the processes.

> *"We were delegated, and we are unable to make budget decisions." We then seek for the approval of the measures and discussed the budget's utilization. Actions aren't taken right away; everything takes time, undergoes a process " (Committee member, 2017).*

Management

The planning of the activities was done in accordance with the lines of action and objectives of each institution, in this way the objectives and activities are aligned, and joint activities were achieved. Regarding the survey, 69.23% members of the committee identified that decision-making was participatory, accountable, and inclusive and 53.84% believed that the planning involved all actors and to a lesser extent (46.15%), that the members had the task of communicating and promoting the committee in their own organisations. This last point is related to internal communication in institutions, bureaucratic procedures and as previously noted, the workload of some officials. Equally the commitment and will of the participants.

Less than half of those interviewed (46.15%) reported that the actions went beyond traditional activities and 53.84% said that the actions were beneficial to the institutions as it allowed them to be more representative in the municipality. However, it should be noted that one of the committee`s goal was to identify the processes and resources of each institution, as well as to link these efforts, to promote and prevent vector-borne diseases. The majority of the members of the committee interviewed (69.23%) agreed that an investment of time, personnel, resources and facilities for implementing the joint work will be needed.

The leadership is a joint action of the association, thus achieving the promotion of concerted actions was identified by 63.46% of respondents. The leadership of the FSFB (research team institution) and UNAD (local university) was mainly identified in the minutes of the steering committee as the sectors leading the process of scaling-up the intervention and the partnership, managing and coordinated meetings, proposing actions.

> "*We can show the progress we have made. Under the leadership of Fundación Santa Fe de Bogotá and UNAD, for example, providing support for teachers and students to improve their research capacity. This gives identity and recognition (...) We have other local committees that aren't yet functioning and have had a lot of problems; nevertheless, our group is expanding and producing results…* " (Committee member, 2017).

In addition, the review of the committee minutes and data obtained from the semi-structured interviews identified the following limitations for the management and operation of the MAC:

- Election periods (local, regional, and national) made the commitment of officials limited.
- The lack of the appointment of a fixed representative per institution or the possession of new governments and new officials in the positions, implied that the activities and objectives of the committee should be re-socialised, thus creating new links with local entities.
- An initial large number of proposed initiatives made it difficult to define specific lines of action with managers responsible for suggestions and / or execution, although the next years' goals were more specific
- The lack of financial resources to maintain the collaboration and further actions that is related to the political will of the major. The municipality, at the end, did not allocate resources for scaling up the intervention.
- Members of the multisectoral committee who work as public officials have a limited amount of time to devote to the meetings and activities of the multisectoral committee.

Another limitation identified in the interviews was the lack of recognition of the MAC and the actions carried both by the participant organisations and the community. Therefore, the MAC was not recognised externally.

> *"*Measuring an impact is complicated, what has been done is diffusion through social networks, which is minimal, dissemination of what the committee does is needed*"* (Committee member, 2017).

Regarding the actions to minimise the barriers to collaboration, all the interviewed members of the MAC assured that there were strategies to ensure alternative views were expressed within the partnership, followed by 92.31% who agreed that there was a core group of skilled and committed members that has kept the partnership alive, and by 76.92% who expressed that there was a formal structure for sharing information and resolving demarcation disputes.

Sustainability of partnership

The evaluation of the MAC investigated the elements and mechanisms necessary for sustainability of the partnership to achieve its outlined goals. It was identified that there is a need and commitment to continue medium-term collaboration (76.92%), but only 30.76% of the members reported that there were resources available to continue, such as personnel, equipment, or materials, which adds to job instability and difficulties in planning of yearly objectives.

It was suggested that there was a need to increase the recognition of the MAC throughout the dissemination of information, in order to present the added value of the committee, its benefits and its presence in the municipality. This can increase adherence and the commitment of the members, thus creating a MAC identity.

> *"Motivation is needed, but not financially, but in the form of recognition of the committee and the participating institutions (...) congratulate the leaders of the institutions and welcome them to be part of the committee" (2017 committee member)*

In addition, it was identified that the meetings should be more dynamic and timely to achieve feasible objectives and the rigorous monitoring of each line of action proposed, and more community meetings should be conducted.

7.4.2 Final remark

> *"How can the committee's impact be observed? If we look at the history of dengue surveillance data (SIVIGILA), we can see that there has been a significant decrease. We know that there are cycles, roughly every three years, and that we would be in our third year with the highest dengue cases; fortunately, based on historical data, we are well below the highest peaks" (Committee member, 2017).*

The main result of the committee was the opportunity for cross-sectoral activities for the prevention and control of diseases transmitted by *Ae. aegypti*. In its first year of operation, the MAC encountered challenges, limitations and elements that strengthened the need for joint actions. The management by FSFB, UNAD and the commitment of the local government (Secretariat of Health) were indispensable, which contextualised the committee in the framework of policy, research, and alliances with different sectors.

The following figure based on the Bases Energy Technical (BET) conceptual multisectoral framework of the WHO for the prevention and control of VBD was drawn up with the results obtained by the evaluation of the "Girardot *Aedes-Free"* multisectoral partnership (16). It was developed with a view to summarizing the results.

The figure groups the necessary elements for the success of the local MSA in three blocks: 1. **Technical elements** which are the **Sectors** that were engaged and that worked together in the **Domains** proposed and that were influenced by limiting or facilitating factors, 2. The **Base** considers the **Dimensions** of the collaboration and three **Pillars** commitment of the local government (mayor, municipality council and Health Secretariat) and national government (MoH), the coordination of sectors by means of a committee and framed in a local policy (IGM-dengue) and community engagement seen since the design of the "Girardot *Aedes-Free*" intervention, and 3. **Energy** that identifies the **Levels** of core coordination that was principally local and the **Resources** mainly from local and national sources.

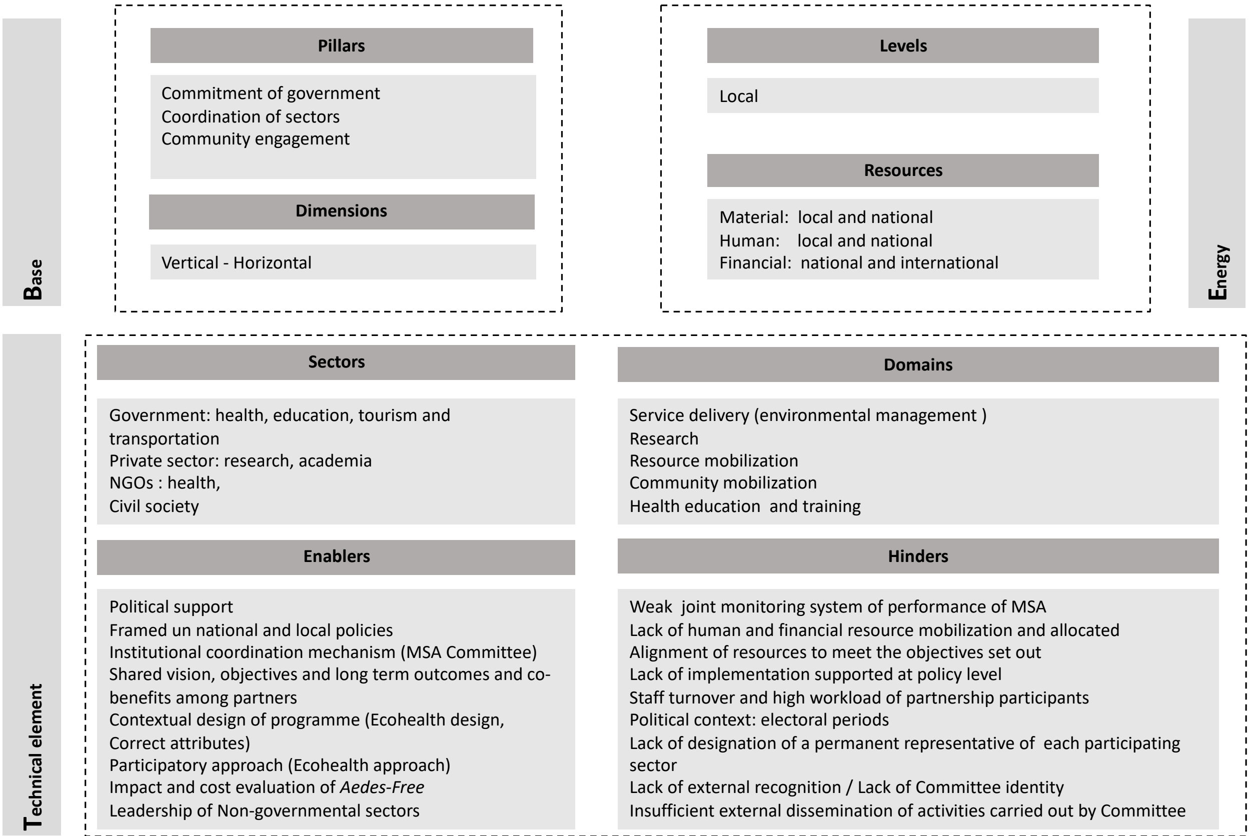

Figure 7.2. BET Conceptual framework for "Girardot *Aedes*-Free" multisectoral action partnership for the prevention and control of VBD in Girardot (Adapted from WHO (16)).

7.5 Discussion

This case study outlines and assesses a multisectoral and intersectoral action established and promoted as part of "Girardot *Aedes-Free"* intervention with the aim of reducing dengue cases and *Ae. aegypti density*. The multisectoral action collaboration was considered an essential component of "Girardot *Aedes-Free"* intervention. This component of the intervention acknowledged that many factors that determine dengue in the population occur outside the direct control of the health sector and consequently should be tackled through action within and between other sectors (education, local government, and tourism among others) (1).

The findings of this case study provide evidence that "Girardot *Aedes-Free"* intervention enabled effective cross- sector collaboration. It acted as a facilitator for the collaboration across sectors as they worked towards a common goal: the prevention and control of VBD transmitted by *Ae. aegypti.* Specifically, the results of the VPAT provide evidence that the partnership within

"Girardot *Aedes-Free"* reached a genuine collaboration, although with some dimensions needing work or representing areas of weakness (such as implementing collaborative action and planning collaborative action). The impact of the proposed and implemented strategies by the multisectoral partnership is demonstrated by the probable decrease in the incidence of dengue and *Ae. aegypti* indices, as described in Chapters 4 and 5 respectively, and in behavioural changes such as increased stakeholder and community participation. Teamwork and the coordination skills of the various stakeholders were also enhanced as a result of their frequent interactions and participation in research activities.

This study underlines the following factors that influenced the success of the multisectoral collaboration:

Context

Effective multisectoral alliances are dependent on context and policies (24,25). In the prevention and control of VBDs, international, regional, national, and local policies that support multisectoral collaborations (IVM, IMS-Dengue) facilitate the initiation and sustainability of such collaboration among sectors. Results evidenced that a multisectoral committee was decreed following two national policies: The Decennial Public Health Plan:2012-2021 (23) and the Integrated Management Strategy (26). Both policies allow and promote multisectoral and intersectoral collaborations and community participation as essential tools for VBD prevention and control in Colombia. Furthermore, the disease burden due to the emerging arbovirus favoured the alliances among sectors. Zika and Chikungunya outbreaks affected the principal income economy (tourism) of Girardot as well as other related activities such as transportation, restaurants, supermarkets, etc. All visualized the benefits of "Girardot *Aedes-Free"* intervention.

Contrary to the former enabling factor, political changes evidenced in the local government due to election periods and regular changes of local government officials during the time frame of the collaboration limited the commitment and decision-making power of actors representing different local governmental sectors. These difficulties have also been noted in other multisectoral collaborations, demonstrating that stakeholders' capacity to engage in partnerships and influence decision-making is dependent on their power, which is hampered by insufficient institutional structures. Therefore, sustainability of multisectoral approach requires a strong political will and technical support that transcend political changes.

Shared vision

As discussed in Chapter 6, building connections among local government officials, diverse local sectors, and community people is critical for scaling up an intervention; nevertheless, differing visions, perspectives and interests among actors hinder partnerships (16,27–30). This case study offers evidence that the actors representing different sectors of the partnership initiated in the frame of "Girardot *Aedes-Free"* intervention shared a common vision and proposed a clear objective. It can be argued that this was facilitated by the emergence of new arboviral diseases (Zika and Chikungunya) causing epidemics and therefore affecting the principal local economic industry (tourism). Actors perceived and scored highly the benefit of the partnership.

Management and resources (governance)

Governance at local level is crucial for the implementation of multisectoral approach in public health interventions. Governance means management and leadership, interaction of actors, decision spaces and multilevel structure, institutional structure and technical capacity of government and accountability (31).

The management of an alliance lies in the tools needed and that are available to achieve the expected results, particularly the resources needed to plan, coordinate, and secure the partnership. No specific resources were identified to manage the partnership, beyond those provided by the project, within the timeframe established for the execution of the project. This project was largely funded by international (IDRC and WHO/TDR) and national (Colciencias) agencies, and its implementation needed to be completed within a specific time frame. Resources have been identified as critical to the multisectoral action, especially the shortage of financial resources, which hampered the process of collaboration and, more importantly, the sustainability of "Girardot *Aedes-Free"* intervention, as discussed in chapter 6.

Leadership is another important part of multisectoral collaboration management. Although this is not a major key factor, it does play a role in the achievement of effective collaboration (18). The academia research team (FSFB) and local universities (UNAD), that led the research project, have social prestige that is expressed in the local contexts where they maintain a constant presence, identified as key for entering the community, establishing and maintaining alliances, and conducting research activities. Both institutions (FSFB and UNAD) represent the non-governmental and private sector that led the partnership since its beginning and were not influenced by the political context constraints. It has been stressed by the WHO (30) and Rasanathan et al. (32,33) that the health sector is usually the principal leader in the maintenance and promotion of the health actions (e.g. controlling VBD transmission), but they can assume other roles in a multisectoral programme other than leading (32,33). Other sectors that may be beyond political constraints can be more effective (16).

Establishing a working group (multisectoral committee) were agreements are established has also been reported as a component of management as a primary mechanism for initiating, establishing and implementing multisectoral collaborations (16,27,30,33), but this did not guarantee sustainability of the partnership. In the case of "Girardot *Aedes-Free"* MSA, a new steering committee was established by the municipality council that worked during the study period, however, its sustainability needs to be addressed further.

Participatory approach

Participation is a common thread in scaling-up processes and Ecohealth initiatives in the prevention and control of VBD, associated with ownership and sustainability of interventions (35). However, it has been reported that when scaling-up an intervention that incorporates participation, costs and time can increase significantly and these are usually not taken into account in project planning (36). Other authors have added that the time and costs involved in large-scale participation make it difficult to implement scaling-up initiatives, for example at the national level (37).

The active participation of different stakeholders and especially the community was identified as fundamental to the development of "Girardot *Aedes-Free"* intervention. Pedagogic and participatory methodologies, such as educational workshops, awareness-raising strategies, participation groups and incentives, were used to encourage the active participation of each stakeholder group. This response to the use of the Ecohealth approach in the design and implementation of "Girardot *Aedes-Free"* Intervention (38,39), as described along in the background chapter and Chapter 3, constituted an opportunity to promote the participation of public and private institutions from across different sectors.

The participation and exchange of ideas with stakeholders was encouraged from the beginning of the research project and during the scaling-up process, which strengthened the institutional and personal links that already existed between the research teams and the government, an element that has been discussed by other authors (40,41). Different participatory activities and strategies were reported to be important for the implementation of the intervention. These were linked to the sustainability of the processes and were supported by ongoing participatory processes in the context of Girardot, which facilitated the scaling-up. Although, promoting participatory approaches does not guarantee success, it is a critical element for the sustainability and ownership of joint collaborations and programmes (42).

In addition, it is important to highlight that participation, can be implemented at local level. That is why a multisectoral approach for VBD (and others) should be conducted at municipal level where the political authority (mayor) can lead the process and has the capacity to put together human, financial, and political resources as well as the infrastructure.

Type of partnerships, entities, sectors, actors, and roles

Xue Yan et al (43) identified five modes of multisectoral partnerships in an urban context: multi-stakeholder partnership, public-private partnership, public-private-people partnership, community-organisational partnerships, and end-user-oriented partnerships. These differ in several aspects, such as in their engagement strategy, relationship among actors and sectors, barriers and drivers that affect participation and influence in impacts. Accordingly, "Girardot *Aedes-Free"* MAC represents a "public-private-people partnership" mode of partnership. This is defined as a "formal cooperation between enterprises, local government officials and citizens with the potential impact to create financial, social, and environment sustainable development through involving all resources from public, private, and people, as well as satisfying their needs" (44).

Actors/sectors in this type of relationship include primarily government agencies, private-sector firms, and people (community members) who play various roles. The private partners are mostly involved in project finance, planning, and management, whereas the public partners are typically involved in project launch and monitoring, as well as serving as end-users (44). "Girardot *Aedes-Free"* intervention involved citizens not only as end users but others, such as community leaders and civil organisations participated in promoting awareness on the prevention and promotion of VBD and in the design and use of container covers for *Aedes*-productive water-holding containers. Public partners represented by the local government (Secretariat of Health) and other public local partners (public schools) focused on creating a suitable environment for the development of the partnership and the implementation of scaling-up the intervention through locating political and human resources respectively. This was complemented by the roles of the private non-governmental entities (research institutions and local universities) that mainly led the partnership due to their expertise and experience and by providing financial resources. Different participating entities provided assets or services according to their own characteristics.

There is no specific rule that determines the number of actors, types of organisations or sectors that should establish a partnership. The range of sectors and type of organisations involved in a partnership will depend on the context, perceived need of each, will and commitment, objectives established, and goals needed to be accomplished within a set time frame (16,24). Although some evidence highlights that non-governmental institutions have a higher likelihood of integrating a collaboration (45), in this case study there was almost equal participation by the type of institution (governmental or non-governmental). What is more important than the type of institution is the role that each assume in, not only leading and proposing activities to reach a common goal, but also in the leadership and involvement in the management of the committee.

Political will, particularly in the form of high-level political support, has been cited as the most important factor for the successful implementation of multisectoral and intersectoral initiatives (46–48). The implementation of a multisectoral approach for the prevention and control of VBD had a strong political will that was achieved in Girardot by obtaining a decree passed by the Municipality Council to establish an intersectoral committee.

Sustainability

The partnership was built with the aim to foster the long-term sustainability, expansion of the actions, and preventing "Girardot *Aedes-Free"* intervention from becoming just another initiative that passes through once external support is withdrawn.

While multisectoral partnership continued during the research period, relationships among actors are more likely to become disconnected over time, as indicated by previous experiences (49). Despite members´ expectations that the collaboration and financial resources would continue beyond the project´s time, and the departure of the research team, there was a lack of facilitation and inadequate resource allocation to sustain, coordinate, and monitor "Girardot *Aedes-Free"* multisectoral effort. Financial and technical support were available mainly from national and international agencies for conducting the study during the study period. MSA was initiated in the framework of "Girardot *Aedes-Free"* intervention scaling-up project. The resources factor is one of the major influencing factors affecting the success of sectoral collaborations on VBD control and prevention (18) and on other primary health care actions (50).

7.6 Limitations

The following limitations of the case study need to be acknowledged. First, a case study based on a single case limits the ability to generalise the findings to other urban contexts as it may not capture the diversity of other experiences. A local context contributes or limits the types of collaborations and success of partnerships. Second, VPAT used to capture diverse dimensions of a partnership (shared mission, vision and goals, roles, and responsibilities, planning and implementing collaborative action, resources, sustainability) was applied once (cross sectional measure) therefore it did not capture changes over time in these specific dimensions. It is a valuable tool that can be used for monitoring the partnership evolution although persons who answer may change over time and may not exactly represent the same perceptions of an actor that represents a sector (self-reported by an actor, a sector may have different actors representing). Furthermore, the validity of VAPT is unknown and translation to Spanish was used. Third, the data reported by key informants was limited to half of the members of the committee, thus underreporting other important factors that could influence the development of cross-sectoral collaborations. Fourth, literature (51–53) has proposed different stages of collaboration (no interaction, networking, cooperation, coordination, coalition and collaboration) and ways to measure it. Although the VAPT and semi structured interviews reported a genuine collaboration of the multisectoral partnership, the study did not measure the level or stage of collaboration between sectors and actors, only the perceived participation and number of times they participated in meetings. This aspect is important as collaboration can change (grow or decrease) over time due to the dynamic nature of partnerships and collaborations and specific roles of partners can be additionally informed.

7.7 Conclusion

This study shows how "Girardot *Aedes-Free*" intervention used a multisectoral collaboration to address *Aedes*-borne disease prevention to achieve collective impacts. This study identified that the development, function, and sustainment of a multisector partnership were influenced by a set of key factors, particularly governance. Governance at local level is crucial for the implementation of multisectoral approach in public health interventions.

Although this evaluation identifies the key factors and the lessons learned about multisectoral collaborations for the prevention and control of VBD, the findings corroborate those in the literature on multisectoral collaboration in other areas, including education, nutrition, non-communicable diseases, and early childhood development. The elements identified can help the approach of other multisectoral committees and some points need to be considered in their functioning, particularly in the frame of the new decennial public health plan 2022-2031.

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Chapter 8 Conclusions

This thesis focused on understanding the effectiveness and the process of implementation of scaling-up "Girardot *Aedes-Free"* that aimed to reduce *Ae. aegypti* indexes and therefore dengue incidence in a hyper-endemic dengue virus municipality of Colombia. The three main objectives proposed in the thesis were interlinked to encompass essential elements of scaling-up effective interventions at a local level. The first objective, investigated evidence of the effectiveness of the intervention (Study 1 and 2), the second aim explored how the intervention was scaled-up towards achieving broader impact and integrated into the local vector control program (expansion and institutionalization of the intervention) (Study 3), and the third objective, investigated the understanding of the role of a multisectoral partnerships as the main strategy towards the expansion and integration of the intervention into local a programme, and reaching sustainability (Study 4).

Figure 8.1, illustrates the overview of how the scaling-up and implementation of "Girardot *Aedes-Free"* intervention was understood and built upon the integration of different frameworks (ExpandNet by WHO, MRC, Fidelity and Implementation science) to ensure a comprehensive assessment of critical issues along with the identification of the mechanisms that mediated the impacts measured as the reduction in *Ae. aegypti* indexes and dengue reported cases. It can be depicted from Figure 8.1 how the innovation (Girardot *Aedes-Free*), the context or environment (outer and inner context), the resource team (promoters of the scaling-up: research team and ITM providers), the user organization (Secretariat of Health) and the beneficiaries interacted and reinforced each other during the process of scaling-up. It illustrates the start of the pathway to reach outcomes, the importance of analysing the intervention in terms of all its components (CORRECT attributes) and understanding implementation by responding to two main questions: how the intervention was delivered (resources used to include the research team, providers, training, and other facilitation strategies) and what was delivered (fidelity). Within the features presented in the figure, elements arose acting as enablers or barriers (resource allocation, leadership of the user organisation, political and economic context and engagement of stakeholders through participatory actions).

It is worth noting that the evidence (1–4) has revealed pathways or characteristics for successful scaling-up interventions/programs. However, it is unclear if compliance with all or some of these issues will lead to significant scaling-up or long-term sustainability. The processes that mediate the success of implementing Girardot *Aedes-Free* intervention at scale and thus the impact of the intervention (reduction in entomological indexes and hence dengue cases), were identified together with the implementation process. Participants' responsiveness (acceptability by both implementers and users) was identified as a mechanism of change in this example. Moreover, the same mechanism may be at work throughout the early stages of deployment (efficacy study).

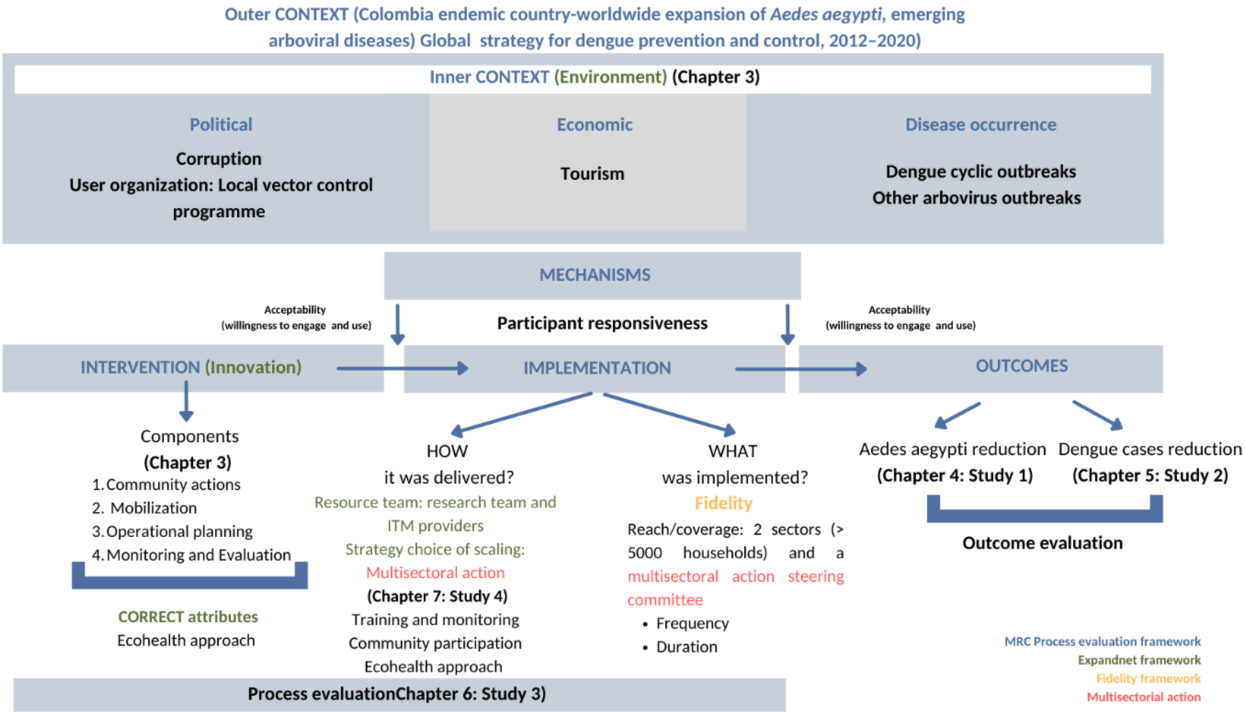

Figure 8.1. **Conceptual framework of Scaling-up and implementation process of "Girardot *Aedes-Free*" intervention**

Process evaluation: of scaling-up and implementing the intervention

The assessment of the process of expansion (horizontal scaling-up) and institutionalisation (vertical scaling-up) of "Girardot *Aedes-Free"* intervention evidenced a nonlinear complex process and the critical elements that influenced it. This study revealed the lessons gained during the scaling-up and implementation of the intervention, as well as what can be accomplished within the time frame considered (project horizon). After two years it was shown that "Girardot *Aedes-Free*" intervention was validated with all social actors involved in the prevention and control of *Aedes*-transmitted diseases. There has been an initial scaling-up of the programme, but more steps are needed to secure total ownership by the user organization or organizations. The facilitating and limiting factors (adequate resource allocation, leadership of the user organization, political setting, and stakeholder participation) for the development and scaling-up of the intervention are mainly contextual factors from the own history and political dynamics of Girardot.

One of the main facilitation strategies was the resource offered by building coalitions between the stakeholders representing different sectors, highlighted in red and named multisectoral action within Figure 8.1. "Girardot *Aedes-Free"* intervention used a multisectoral partnership to address *Aedes*-borne disease prevention and achieve collective impacts, as presented in study 4. A collection of critical characteristics influenced the establishment, function, and sustainability of a multisector cooperation, according to this study (contextual, management, funding, type of actors and sectors among others). The intervention was not institutionalised within the local health and vector control plans, however, the multisectoral action was built and structured under a committee and this was a critical element for promoting the scaling-up and other vector control actions. Girardot can be considered an appropriate scenario to explore and promote multisectoral actions and policies given the contextual characteristics and local problems but governance at local (municipal) level is crucial for the implementation of multisectoral approach in public health interventions. This multisectoral approach means "health in all policies" that should come from the highest level of government to state and local level.

Outcome evaluation: effectiveness of the intervention

The aim of dengue vector control is to maintain *Ae. aegypti* populations below or close to minimal disease transmission thresholds, slow the force of dengue-virus transmission, and reduce sequential infections with different serotypes. The study found that covering productive household water containers with insecticide lids has a positive impact for controlling *Aedes* immature production in households and in combination with other community actions increased the success in reducing *Ae. aegypti* in both household and public premises. Furthermore, this study indicated although not conclusive a reduction in dengue incidence compared to control sites, although this is probably an underestimate of the true potential of the intervention considering that approximately 20% of cases were not identified for analysis. Greater coverage—in particular, reaching other sectors and other high-risk transmission areas (public spaces such as schools and commercial recreation sites)—and an improved surveillance system are required for maximizing the effect of the intervention.

The results of this thesis can serve as a basis for future studies on the effects of the intervention and can inform decision-making regarding any scale-up initiative. Nowadays, several new vector control interventions are being tested in Colombia, in different settings. If these new interventions are found to be effective, they should be scaled-up and introduced them into local programs. The elements that were assessed as part of the thesis provide useful information on how to scale-up an intervention and what factors must be addressed. Furthermore, the evaluation of the multisectoral partnership as part of a vector control intervention will help strengthen other partnerships that have been implemented in Colombia following national guidelines and yet are not sustainable and not functioning.

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Appendixes

Appendix A. Literature review: Effectiveness of *Aedes* vector control interventions

Appendix A1. Literature review of *Aedes* control interventions

Pubmed and Cochrane Library electronic databases from January 2007 to June 15, 2017, were accessed. The review considered any systematic literature review (SLR) and metanalysis studies that evaluated more than one *Aedes* vector control intervention without limitation for country. Studies published in English and Spanish were considered for inclusion. The references listed in the identified publications were reviewed for additional references. The terms used were: “((dengue[Title/Abstract]) OR aedes[Title/Abstract]) AND "effectiveness"[Title/Abstract] OR efficacy OR evaluation [Title/Abstract], AND "prevention and control"[All Fields] using any combination of the terms prevention, control, and dengue or *Aedes* interventions.

The search until June 15, 2017, produced a list of 351 articles. After reviewing the titles, 343 were excluded as did not meet the inclusion criteria (88 reporting reviews, 43 SLR, and 212 reporting other research areas like economic evaluations, surveillance, or single interventions). Eight studies were fully assessed, one was excluded for analysis and after reviewing the references one additional article was identified (Table 1). The search was updated on October 31, 2017, and a new systematic review was identified (Table 1). Eight articles were fully assessed of which four are meta-analysis, three are SLR and one is a meta-review. All studies were published between 2007 and 2017, the majority (75%) from the last three years. The number of studies included varied across the SLRs (between 11 and 56 studies) and included mainly meta-analysis, Randomized Control Trials (RCT), Cluster Randomised Control Trials (cRCT) or Non-Randomised Control Trials (NRCT).

The most recent review was published by Horstick and Runge-Razinger (1). The authors aimed to assess the evidence of vector control interventions which provide protection against different vector borne diseases (Chagas disease, dengue, leishmaniosis and lymphatic filariasis) at the household level. They included studies published between 1995 and 2015 that focused on interventions oriented to reduce disease incidence through vector control indoor and outdoor reservoir control. The type of interventions included were insecticide spraying, insecticide-treated materials (curtains, nets or covers) and the control of breeding sites by chemical, biological or environmental methods. The strongest evidence of efficacy was found for insecticide- treated materials (ITM) as curtains, container covers and screens and for treating larva habits with chemical or biological control. The interventions that were less effective or had no effect included clean up campaigns and waste management as they depend in a sustained collaboration of communities. As a general issue, the authors pointed out the low quality of study designs and recommended that Cluster Randomised Controlled Trials (cRCT) and Randomised Controlled Trials (RCT) that include criteria of sample size, time of follow-up and outcomes of disease transmission should be done in the future.

The second most recent systematic review was published by Alvarado-Castro et al in 2017 (2) which includes a meta-analysis. The authors assessed the evidence published between 2002 and 2015 of the effectiveness of different control measures in reducing *Aedes aegypti* tested throughout cRCT. The authors analysed 18 cRCT evaluating chemical control interventions (8), biological control methods (1) and community mobilisation and participation interventions (9) conducted in 13 countries mainly in Asia and Latin America. They concluded that the most effective intervention were those that combine community mobilisation and participation with routine government control services, rubbish collection, covering water containers or removal of water containers The most common characteristic of this type of intervention are: engagement of stakeholders in vector control planning and implementing activities, households visits to support removal of breeding sites, educational programmes, joint collaboration with local services. In addition, the authors affirmed that future trials should measure the impact on disease risk.

The meta-review reported in 2016 and conducted by Bouzid et al (3) included recent primary studies about the effectiveness of chemical, biological, educational and integrated vector control strategies and searched for other recent primary studies that were not included in any systematic review. This meta-review found that the effect of vector control interventions was mainly measured using entomological parameters (indicators of vector density). Few studies used disease incidence indicators. Biological control was found to achieve a greater reduction of mosquito populations than chemical control. Educational campaigns were found to be essential in reducing breeding sites and interrupting disease transmission. Integrated vector control strategies may not always increase effectiveness, the effectiveness of any control strategy is setting – dependent. Other promising novel vector control strategies being tested would be a valuable addition to control mosquito-borne diseases. For example, results from cRCT in Latin America (Brazil, Colombia, Uruguay and Mexico) reported significant reduction of vector densities following community-based multiple interventions (such as environmental management or clean-up campaigns, the formation of community working groups, social mobilization strategies, water covers and window screens using insecticide-treated nets, and use of larvicides).

Bowman et al. in 2016 (4) , presented a systematic review including 41 studies (from 5 months to 10 years duration). The authors found no evidence that skin repellents, bed nets and mosquito traps reduced dengue incidence. Additionally, mosquito coils were associated with higher dengue risk. They described the unusual situation of the limited available evidence from RCT to determine the effectiveness of outdoor fogging, as this is one of the main tools used in outbreaks. Nonetheless, methods such as house screening and community-based environmental management with water container covers were shown to be a protective measure against disease transmission. The most recent methods, such as the use of Wolbachia demonstrated impact on the vector population only. However, the authors emphasise that the quality of the studies included is weak resulting in inadequate evidence for decision making, therefore, standardized, and higher quality studies are urgently needed.

Ballenger-Browning et al in 2009 (5), reviewed the effectiveness of three types of dengue vector control interventions: chemical, biological and educational in reducing entomological indicators. The review included 21 studies that ranged from CRT, non-randomized to interrupted time series designs without restriction per country. The authors found that the primary measures for monitoring immature stages of the vector were the Breteau, House and Container indexes.

The earliest systematic reviews were reported in 2008 by Erlanger et al (6) and in 2007 by Heintze et al (7) . Erlanger et al, compared the effects of different dengue vector control interventions (Chemical and biological control, environment management and integrated vector management) in entomological indexes (Breteau, Container, and House index). They covered a period between 1945 and 2007, reviewed 56 publications and concluded that from 61 dengue interventions described, community-based and integrated approaches for dengue vector control interventions are more effective in reducing entomological indexes. Heintze et al, assessed 11 studies that assessed the effectiveness of community-based interventions alone or in combination with other vector control measures. The effectiveness was determined by the reduction of entomological indexes (Container, House and Breteau indexes). The authors concluded that the evidence presents methodological weaknesses in the design of the studies.

Table A-1. Summary of studies reporting systematic literatures reviews and meta-analysis on multiple *Aedes* control from the past 10 years (2007-2017)

Author, year	Type of review, type and number of studies included	Vector control interventions	Conclusions
Horstick et al, 2017 (1)	SLR cRCT and parallel group cRCT 32	Interventions providing protection against Chagas, Leishmaniosis, dengue and lymphatic filariasis at household level.	- Interventions aiming to protect house and its surroundings might affect the transmission of several diseases. - The most effective interventions in providing protection against multiple diseases are indoor spraying, insecticide treated materials (nets and curtains) and treating larva habits with biological and chemical methods. - Very few high-quality studies are available. - The evidence for vector control is weak when measures disease transmission. - Quality of deliver is crucial.

Alvarado-Castro et al 2017 (2)	SLR and meta-analysis 18 cRCT and 10 for meta-analysis	Different control methods alone or in combination	- The most consistently effective intervention was community mobilisation. - More well conducted trials of complex interventions are needed. - Future trials should measure disease transmission.
Bouzid et al, 2016 (3)	Meta review 13 (9 SLR 4 SLR + MA)	Any control method	- The SLR suggest that biological control archives better and more sustainable reduction of entomological indices than chemical control. - Educational campaigns ad community engagement appear paramount in reducing breeding habits in peridomestic environment. - Chemical control could be associated with a false sense of security leading to lesser community engagement with reduction/ elimination of breeding sites. - Most reviews were considered to be of low to very low quality. - More high-quality primary studies and well conducted SLR are still required.

Bowman et al 2016, (4)	SLR and meta-analysis 39 (7 cRCT, 2 RCT, 8 NRCT, 11 ITS, 5 BA, 6 Observational)	Different control methods alone or in combination	- No RCT evaluated effectiveness of space spraying. - Limited evidence indication that house screening and community-base, environmental management with container covers reduce dengue transmission. - Lack of evidence for the effectiveness on any dengue vector control intervention. - Higher quality standardised trials are needed that includes measurement of impact in disease transmission.
Lima et al, 2015 (8)	SLR and meta-analysis 26 and 22 for meta-analysis (6 cRCT, 16 NRCT, 4 BA)	Biological, chemical, mechanical, and integrated vector management	- 2 effective methods: 1. Integrated approach considering eco bio social determinants in the virus-vector-man chain 2. Community empowerment as active agents of vector control. - Chemical control alone showed the worst performance.
Erlanger et al, 2008 (6)	SLR and meta-analysis	Biological, chemical, environmental management	- Most effective interventions are community-based, integrated approached and tailored to local

	56 (2 cRCT, 2 RCT, 23 NRCT, 2 ITS, 24 BA, 3 Observational)	and integrated vector management	settings and combined with educational programmes. - Integrated management was found to be the most effective methods to reduce entomological indices and targeted large populations. - Environmental management showed relatively low effectiveness for reducing indices - Biological control targeted small number of people
Heintze et al, 2007 (7)	SLR 11 (2 RCT, 3 ITS, 6 BA)	Community-based interventions alone or in combination with other measures	- Weak evidence for the effectiveness of community-based programmes alone or in combination - Studies varied with respect to targeted population - Methodological weakness found in all studies

SLR (Systematic Literature Review), MA (Meta-analysis), RCT (Randomised Controlled Trials), cRCT (Cluster Randomised Controlled Trials), NRCT (Non-Randomised Controlled Trials), ITS (Interrupted Time Series), BA (Before-After).

Table A-2. Detailed characteristics of studies reviewed analysing *Aedes* control interventions

Author Year	Objective	Study characteristics 1.Type of Review 2. Period covered 3.Inclusion criteria 4. Measure of effectiveness	Main results and conclusions
Horstick et al, 2017 (1)	To assess the evidence of vector control interventions applied in practice, which provide protection against Chagas disease, dengue, leishmaniasis, and lymphatic filariasis at household level.	Qualitative systematic literature review (SLR) 1995 – 2015 Type of diseases: dengue, Chagas disease, leishmaniasis and lymphatic filariasis 12 studies focused on dengue from which 8 were done in Latin America, 13 studies on Leishmaniasis, 7 studies on Chagas disease, Sample sizes varied across studies, variation in follow-ups	**Data only for dengue:** ***Insecticide spraying:*** Malathion UVL spraying + educational campaign: Larva positive container pre 0.53 post OR 0.326 ***Insecticide treated materials:*** ***Screens:*** House infestation rate after 5 months OR 0.38, IRR 0.39 House infestation rate after 12 months OR 0.41, IRR 0.49

	and outcome measures varied between studies Type of studies: CRT and cRCT Types of interventions: any intervention aimed to reduce disease incidence through vector or reservoir control in and around a house or dwelling Positive, negative, or mixed results. Measures used for dengue interventions: Entomological proxy indices BI, CI, HI and PPI, self-reported cases, serological measures, adult mosquito measures, ovitrap, oviposition indices, presence of indoor resting adult mosquitoes and rates of house infestation	***Curtains:*** ***Mexico & Venezuela:*** *Mexico:* PPI pre 3.4, post 0.36 at 12 months *Venezuela:* PPI pre 3.0, post 0.3 at 12 months. IgM pre 16% post 8% intervention group. IgM pre 21% to post 18%. *Thailand**:*** no differences, intervention setting: open houses ***Curtains and container covers:*** *Colombia:* BI 14 pre, 6 post intervention, BI 8 pre, 5 post in control. ***Screens + spinosad:*** Mexico: PPI 0.2 pre, 0.023 post in rainy season. ***Biological and environmental methods:*** ***Thailand (Mesocyclops, Bti, screen nets for jars, mosquito traps, vacuum aspirators):*** no differences between Hi, CI, BI. PPI: 0.19 pre, 0.05 post intervention group vs 0.73 pre, 0.26 post control group) ***Nicaragua (emptying, brushing, scrubbing container walls, covering receptacles, clean up campaigns, and community mobilisation):*** reduction of entomological indicators HI by

	44.1%, CI 36.7%, BI 35.1% and PPI by 51.7%; dengue case reduction by 24.6%. ***India (water covers, clean up campaigns and mobilisation):*** PPI 10.75 pre, 0.004 post, HI 19.6% pre, 4.2% post, CI 8.91% pre, 1.5% post, BI 30.8% pre, 4.3% post. ***Brazil (clean-up campaign, container cover and mobilisation):*** not effect on PPI (0.0229 pre, 0.0292) intervention cluster. Bigger increases compared to control clusters. ***Environmental methods only:*** ***Sri Lanka: PPI reduction intervention group:*** 92.8% vs 71.6% in control group. **-** Less promising results ***Conclusions:*** Need of additional randomised trials that assess the measures of human disease and eventually target several diseases with a combination of interventions to protect the household against different vectors

Alvarado-Castro et al, 2017 (2)	To review the effectiveness of interventions for dengue vector control, specifically as measured in Cluster Randomised Trials (CRTs).	Metanalysis January 2003 and October 2016 CRT Studies assessing the impact of chemical control, biological control or community mobilisation, alone or in combination. 18 studies that covered 13 countries Bias per study: 8 low risk and 10: unclear risk of bias. Studies providing information about at least one of the three standard *Aedes aegypti* indices *Single intervention effectiveness: d*ifference between the intervention group and the control group at the last point of measurement in entomological indices (HI, CI and BI)*	**Types of Interventions:** Chemical control interventions: 8 studies - 5: ITM for windows (curtains or screens) ○ 1 single intervention ○ 2 combined with ITM container covers ○ 2 combined with temephos 1 ITM bed bed-nets as single intervention 1 Temephos as single intervention 1 Lethal ovitraps and BTI** - Temephos trial: BI and CI slightly lower in control than intervention areas - ITM as curtains or screens: ○ 3 with impact on PPI - Bed nets alone: BI impact at 6 months not maintained if only one third of the household used the intervention. - ITM screen or curtains plus container covers: reduction in PPI plus other indexes - Lethal ovitraps and Bti: no difference in indexes between intervention and control clusters - Duration of follow-up: between 6 weeks to 18 months

	by type of intervention. *Global intervention effectiveness: o*verall risk difference with 95% CI for each entomological index	Biological intervention: 1 study - Copepods or Bti in household containers plus community mobilisation meetings recruitment of ecohealth volunteers. HI, CI BI significantly lower at follow-up but not so in control compare with intervention clusters. - PPI: significantly lower in intervention that in control clusters at all time points. Community mobilisation: 9 studies - Features of interventions: complex, engagement of local stakeholders, engagement of community members, household visits, partnerships with local services, efforts to improve local services (ex. garbage collection), routine government vector control activities continued intervention and control areas, varies from small trials (3 intervention clusters), medium trials (16 intervention clusters) and large trials (75 intervention clusters) and duration of follow-up: between 5 months to 24 months - 4 studies reported significant reduction in entomological indices at last follow-up between intervention and control areas, 5 studies reported a significant impact on at least

one entomological index and one of the studies found significant impact on children dengue infection and on self-reported cases.

Meta-analysis:

- 10 studies included
- Overall impact Chemical control : HI : -0.01 (95% CI -0.05 - 0.03), CI : 0.01 (95% CI -0.01 - 0.02) and BI : 0.01 (95% CI -0.03 - 0.05)
- Overall impact biological control : HI : -0.02 (95% CI -0.07- 0.03), CI : -0.02 (95% CI -0.04- -0.01) and BI : -0.08 (95% CI-0.15- -0.01)
- Overall impact community participation : HI : -0.10 (95% CI -0.23- 0.00), CI : -0.03 (95% CI -0.05- -0.01) and BI : -0.13 (95% CI-0.22- -0.05)

Conclusions:

- Community mobilisation programmes are effective interventions
- Biological control may have operational limitations for large scale application
- Cluster trials consider community level dynamics

			- Sustainable community engagement includes local evaluation of evidence and co-designing interventions that best suit their local conditions and culture. - More CRCT of complex intervention are needed to provide evidence of real-life impact. - Future trials of interventions of all kinds should include measurement of impact on dengue infection as well as on entomological indices.
Bouzid, et al 2016 (3)	To conduct a meta-review to assess and synthesise evidence from systematic reviews and meta-analysis that investigated the effectiveness of any *Aedes* control interventions or protective measures	Meta review January 2011 to May 2016 Systematic reviews reporting on the effectiveness of *Aedes* control measures 13 studies that the majority dealt with dengue control Pooled effect size of entomological indices or clinical outcomes and descriptive analysis.	***Types of Interventions:*** - Chemical control (insecticides and larvicides): in 8 reviews - 8 reported effects on entomological indexes 4 in dengue incidence - Include: insecticide spraying, ITM and larvicides (temephos) - **Biological control: in 6 reviews** - All reported entomological indices - 2 reported on dengue cases - Includes: copepods (5), Bti(4),

against *Aedes transmitted* diseases.	- **Educational campaigns** (training and awareness of general public to reduce /eliminate breeding sites): in 4 reviews - **A**ll reviews reported on entomological indices - 1 reported on dengue incidence. - ***Integrated vector contro***l (two or more individual control strategies): in 9 reviews - *All reported entomological indices* **Impact** **Chemical control:** - Adulticiding : ○ Bowman (indoor outdoor insecticide spraying): From 19 primary studies. 3 studies included: lower dengue incidence: OR 0.67 (95% CI 0.22-2.11) ○ Das: (insecticide spraying and aerosol) 17 primary studies, 9 studies included : HI: RR 0.90 (95% CI 0.86-0.95) ○ Ballanger (insecticide, larvicide, ovitrap) reported 27% reduction in entomological indices after chemical control

- Erlanger: reported 76% reduction in BI after outdoor spraying (Relative effectiveness: 0.24 (95% CI 0.05-1.19)
- Esu: 15 studies: on per domestic spraying considered poor quality

- Larviciding
  - George: (temephos) 14 studies: no pooled effects. When used alone post reduction in immature stages are observed compared to control. Quality of evidence low. Results depending on season application, number of applications, dosage, procedure of control and method of application.
- ITN (curtains and screens):
  - Bowman: 2 trials: BI -25.16 (95% CI 76.03 – 25.71), HI -10.58 (95% CI -32.22 – 11.05),
  - Screens dengue incidence: OR 0.22 (95% CI 0.05 – 0.93)
  - Bed nets: dengue incidence: OR 0.91 (no statistical significance)
- Dans: 2 studies CRT, and 2 pre post 70% reduction of dengue positive serotype RR 0.30, 95% CI 0.23-0.38

- Wilson: nets, curtains and screens: 4 CRTS, 1 pre-post 80 % ((95%CI 53-92%) of protective efficacy of screens , IGM positivity
  - Insecticide resistance
  - Low quality studies
- Lima: (spraying, growth regulators ITM): 5 studies with contemporary control groups, statistical significance but poor quality of studies.

Biological control:

- Copepods:
- Lazaro: 11 NRCT with contemporary comparator
- Poor quality of studies
- Effective in 1 study on larva and adult control and dengue incidence. But success attributed to community participation.
- Larvivorus fish:
- Han: 10 studies

Conclusion: The evidence is mixed. Chemical control is the most used. Need more quality studies to assess the impact.

Bowman et al, 2016 (4)	To systematically review randomized and non-randomized studies to evaluate the evidence of the effectiveness of vector control interventions in reducing *Aedes sp* vector indices and human DENV infection or disease.	SLR and meta-analysis 1980 to 10th January 2015 RCT, NRCT, any study where vector control tools (single or combined) were used for more than 3 months Any study with empirical data reporting dengue incident and entomological indices monitored longitudinally for the duration of the intervention. 41 studies, 19 for meta-analysis, duration of studies: 5 to 10 years, 23 studies: evaluated multiple interventions, 19 environmental management most common tool, 9: RCT, 2: evaluated dengue incidence under RCT but not significant impact reported.	***-Meta-analysis: RCT*** **-House screening:** 3 studies dengue risk: OR 0.22 (95%CI 0.05-0.93, p= 0.04) **- Combined community interventions with container covers**: OR 0.22 (95%CI 0.15-0.32, P=0.0001) **- IRS:** OR 0.067 **(**95%CI 0.22-2.11, p=0.50) Skin repellents: OR: 1.02 (95%CI0.71-1.47, p=0.91) **Insecticede aereosols:** OR:2.03, 95%CI 1.44-2.86, p=0.01). Only 9 evaluated the insecticide susceptibility status of the vector population. ***Conclusions:*** Paucity of reliable evidence fir effectiveness of dengue vector control tools. Standardised studies are needed.

		Dengue cases reported either by the study or obtained from external institutions. Dengue incidence (any reported case data, clinical or lab confirmed/serologically positive cases) Vector indexes: BI, HI, CI, tank positivity, number of mosquito adults, PPI, presence of *Aedes* immature forms and ovitrap positivity.	
Ballanger-Browing et al, 2009 (5)	To systematically review the effectiveness of biological, chemical, and educational dengue fever prevention programs	SLR July 2007 to January 2008 Vector control programs targeting *Aedes aegypti* and *Aedes albopictus*	***Types of Interventions:*** ***Chemical control***: 7 studies - Insecticide spraying and or chemical larvicide, Insecticide treated materials, insecticide treated strip in an ovitrap - Follow-ups: 7 days – 5 months - Mean reduction 27.2% (73.8 – 13.9%)

	on the reduction of entomologic indicators.	Type of studies: cRCT, RCT, Controlled trials (CT), interrupted times series (ITS). Entomological indices BI, CI, HI and PPI, larva density index, ovitrap index (OI), adult density, indoor landing density, Percentage reductions of BI, or CI or OI by Mullas formula	- Most significant reductions at 5 months with ovitraps - 4 studies CT, 1 ITS, 2 cRCT - May not be a long-term solution due to the short-term effectiveness of the products. - Widespread of chemical resistance - High community involvement is needed ***Biological control:*** 6 studies - Copepods, turtles, Bti - Follow-ups: 2 months – 3 years - Mean reduction 96.3% (75.1-100%) - 5 studies used CT and 1 RCT ***Behavioural***: 5 studies - Mean reduction 41.6% (4.0-87.6%) - Follow ups: 18 weeks – 15 months - Essential for the sustainability of methods - The efforts should neither purley top down nor bottom up but instead utilize the strengths of each level ***Chemical and behavioural***: 1 ***Biological and behavioural***: 2

			Conclusions: - Little concrete evidence to support the efficacy of mosquito abatement programs on reducing incidence of dengue fever - Weak study designs and poorly reported statistics - An optimally integrated approach needed for success. - Creation of standard entomological index, use of cluster and randomized controlled trials and testing the generalizability of proven methods to recommend for future research - Serological surveillance should be necessary component.
Heintze et al 2007 (7)	To provide a systematic and comprehensive overview of the available evidence for the effectiveness of community-based interventions in reducing vector populations for dengue control.	Qualitative systematic literature review (SLR) Until March 2005 Type of studies: RCT, CT, before after, ITS 2 studies RCT, 6 studies before after, 3 studies ITS, Most studies compared intervention vs untreated communities, 7 studies used	***Community- based dengue control:*** - 5 studies Intervention vs control, Baseline vs follow up: *1. HI 3.71% vs 0.61 % vs 1.31%vs 1.65%* *2. HI NR vs 23.4% vs NR vs 38.1 %* 3. CI 26.6% vs 19.7% vs 31.4% vs 24.2% 4. BI 32% vs 34% vs 25% vs 46% 5. Baseline – follow up: HI 21% vs 0%

	educational materials, 9 studies educational meetings, 8 studies educational outreach visits, 6 involved local opinion of community leaders and 5 used mass media - Targeted groups: schoolchildren, teachers, and women Trials evaluating community-based dengue control interventions (was defined as any intervention in which at least one component targeted the community (education meeting, inclusion of local leaders) Measures used for dengue interventions: Entomological proxy indices BI, CI, HI	***Community- based dengue control + chemical larvicides:*** -2 studies Baseline – follow up: 1. BI 97.3% vs 70%, HI 54% vs 41.17 %, CI: 35% vs 31.2% 2. BI 79% vs 34.45, HI 39.1% vs 10.0% ***Community-based dengue control + fish + chemical larvicides*** - 2 studies Intervention vs control Baseline – follow up: 1. HI 58.8% vs 0% vs 80% vs 60%, CI 100% vs 15.8% vs 85% vs 83.3% Baseline – follow up: 2. BI 54.0% vs 1.2% ***Community-based dengue control + mesocyclops*** - 2 studies Intervention vs control Baseline – follow up 1. Dengue incidence 1541/100000 vs 0/10000 vs not reported 2. BI 0-57% vs 0-3% vs 23-53% vs 30-35%

	Conclusions: the future research should aim at distinguishing which specific components of the intervention strategy in combination with community participation and or other partnerships, have the greatest impact on dengue control and are cost effective.

Appendix A2. Effectiveness of impregnated materials for the prevention and control of *Aedes aegypti*

The Integrated Vector Management Strategy (IVM) (9) established by the World Health Organization (WHO) considers the use of combined effective tools based on the local knowledge of the biology and ecology of the vector and of the epidemiology of the diseases that they transmit. It promotes multiple vector control tools targeted to one disease or a single tool for the prevention and control of various diseases with the aim to enhance synergies between disease control techniques and accomplish, therefore, more cost-effective vector control. As stated previously, there are many tools available, with varying degrees of efficacy. This section reviews the insecticide-treated materials (ITM) as a tool for control and prevention Chapter 4.

To assess the effectiveness of ITM used as curtains, screens, water container covers or nets in controlling *Aedes*-disease transmission and vector indexes a new search of the literature was conducted. Pubmed was accessed. The period of search was between 2007 to June 15, 2017. Individual or cRCT that evaluated ITM or the prevention and control of *Aedes*-borne diseases without limitation for country or publication status were considered. Studies published in English and Spanish were selected for inclusion. The terms used were: “((denge[Title/Abstract]) OR aedes[Title/Abstract]) AND "effectiveness"[Title/Abstract] OR efficacy OR evaluation [Title/Abstract], AND "prevention and control"[All Fields] using any combination of the terms prevention, control, and dengue or *Aedes* interventions, covers, curtains, window screens, door screens, long lasting insecticide treated nets. The search retrieved 303 studies. After reviewing the titles, 15 potentially relevant studies were identified. Of these, 7 were excluded as they only reported one of the following outcomes: costs (3), determinants of coverage and use of ITM (2), evaluation of damage of ITM (1) and a SLR already reported in the first section of the literature review (1). In addition, the references of the included trials were manually searched, and 7 studies were identified. These reported the use of insecticide treated curtains and covers (1 trial before 2007, 1 using curtains and covers, 2 reporting container covers, 1 reporting door and window screens, 2 reporting curtains from which one was conducted in a low *Aedes* infestation setting).

Fifthteen articles were fully assessed and included for the analysis (Table A-3). The majority (73%), of the included trials were cRCT, 1 individual RCT, one factorial cRCT, one SLR and one before after study. Ten trials were conducted in Latin America (Mexico, Guatemala Colombia, and Venezuela), three in Thailand and two in the Caribbean (Cuba and Haiti). Fourteen trials were conducted in endemic areas and high vector infestation rates except for one trial that was conducted in a very low *Aedes* density area (Cuba). Six evaluated the effectiveness of insecticide treated curtains or screens, 2 of water container covers alone, while five examined the impact of both. Almost half (n= 8 (53%) of the trials compared the treated materials with routine vector control programme activities.

Table A-3. Characteristics of studies reporting trials evaluating the efficacy of Insecticide treated materials for the control of *Ae. aegypti.*

Author Year	Country/ Site	Study design Time of follow-up Outcomes Analysis	Sample size /Interventions: Intervention	Sample size /Interventions: Control	Main Results
Bed Nets					
Lenhart et al, 2008 (10)	Haiti, Leogane	cRCT 1 month and 5 months, 12 months BI, HI, CI PPI, oviposition activity Attitudes: use and acceptance of bednets by informal interviews.	9 clusters: 55 houses (35-94) ITN Olyset bednets, average 2 bednets per house	9 clusters: 58 houses (47-69) No intervention At 6 months :ITN	Intervention vs control: Baseline- 5 month: HI %: 12.7 vs 5.7 vs 11.5 vs 3.3 CI %: 3.5 vs 1.5 vs3.4 vs 0.6 BI: 17.3 vs 7.2 vs 13.8 vs 3.6 PPI: 2.1 vs 0.1 vs 2.7 vs 0.2 After 12 months from baseline, 5 from bed nets implementation: all indices were significantly lower

		Seroprevalence IgM (baseline and 12 months): 20% of houses included for serological survey WHO bioassays T test to compare intervention and control areas and base line vs follow-up			Control houses located 50 m of a bednet had significantly lower CI and PPI suggesting spill over effect. Serological survey: significant decrease in the number of IgM positive individuals from 33.7% at baseline to 18.5% at 12 months later. WHO bioassays: low mortality 15% at 10 months. Acceptance: at 12 months 95% had bednets hanging, 52.2% slept under the bednet. ITN had an immediate effect and continued to affect vector population and dengue transmission after 5 -12 months.
Insecticide Treated Curtains					
Toledo et al, 2015 (11)	Cuba, Guantanamo	cRCT 12 and 18 months HI, BI, ITC uptake	6 clusters: 3061 households	6 clusters: 3737 households Routine Aedes control	Intervention vs control: Baseline -12 months follow-up: HI: 0.09 vs 0.18 vs 0.17 vs 0.25 Baseline- 18 months follow-up: HI: 0.09 vs 0.17 vs 0.17 vs 0.21

		WHO bioassays Generalized linear random effect regression models with negative binominal function: pre-post interventions and trial arm effect on monthly data. Per cluster level. Cost evaluation.	ITC PermaNet plus routine Aedes control programme Maximum number of curtains 3 per house	programme: monthly inspections of premises, temephos, elimination breeding sites, indoor spatial fogging every 7 - 22 days	No significant differences Rate Ratio: 12 months: 1.07 (95%CI 0.42-2.37) 18 months: 1.15 (95%CI 0.57-2.34) Bioassay: 99.7% mortality rate Curtain uptake and use were high and sustained: at 12 months 97% of the houses used at least 1 curtain. Costs: 3.8US$ (annualized) per household covered Deployment of ITC in a setting with already intensive routine Aedes control actions does not lead to further reductions in infestation levels
Lenhart et al, 2013(12)	Thailand / Phang Nga	cRCT 3.6 and 9 months BI, CI, HI, PPI: baseline 1 week, and follow-ups Insecticide susceptibility.	13 clusters: 1039 houses (31-173 per cluster) ITC (PermaNet)	13 clusters: 998 houses (34-165 per cluster) No Intervention	No differences between groups Ratio of geometric mean AUC: BI: 1.11 (95% CI 0.66-1.87) HI: 1.02 (95% CI 0.74-1.43) CI: 1.34 (95% CI 0.86-2.09) PPI: 1.36 (95% CI 0.78-2.39) Oviposition indices lower in intervention group after 6 months

		Area under the Curve (AUC)			Oviposition rates: intra: 27.5 vs 48.7 and outdoor : 47.5 vs 94 WHO bioassay: 84% at 6 months, 90% at 9 months Open wood and thatch households Use of ITC drop with time 70.5% at month 9.
Vanlerbergh e et al, 2013 (13)	Thailand / Lae Chabang	cRCT 6 and18 months for half of the houses BI, CI, HI, PPI Ovitraps: inside and outside of households before Intervention ITC coverage: % of houses with at least 1 ITC, mean of ITC per houses	22 clusters: 2032 houses (80-100 per cluster) ITC (PermaNet) maximum 5 per house (4 window 1 door) distributed by village health volunteers	66 clusters: 10 houses Routine dengue-related activities performed by the local health authorities (larvicide, fogging)	Bioassays: pre intervention 87% post intervention 84% Intervention vs control Baseline: HI: 17.5% vs 39.5% BI: 25.8% vs 77.6% PPI: 0.21 vs 0.57 6 months: HI: 14.2% vs 19.1% BI: 21.8% vs 23.8% PPI: 0.19 vs 0.09 At 6 months BI was coverage dependent and at 18 months the presence of ITC not affected entomological indices IRR: BI: 0.80 (95% CI: 0.53-1.20)

		Generalized linear random effect regression models with negative binomial link Who bioassays			Use of ITC at 6 month: 70.5%, at 18 months: 33.2% Coverage dependent, small households Additional promotional activities or community need to take place to sustain ITC coverage at high level over time
Lorono-Pino et al 2013 (14)	Mexico, Merida	Randomised Trial 12 month follow-up Outcomes: Prevalence of DENV DENV in humans (Serosurveys: during installation of ITC, after DEN peak, following year (IgM and Rt-PCR, PRNT) Number of females Ae aegypti and	206 households ITC (deltamethrin 80mg/m2)	205 households Non ITC	Prevalence of DENV in *Aedes* Pre intervention: ITC vs Non ITC: 0.0% vs 0.3% Post- intervention: ITC vs Non ITC: 0.4% vs 1.1% Prevalence of DENV in humans (no statistically significant differences): Pre intervention: ITC vs Non ITC: 24.6% vs 25.1% Post intervention: ITC vs Non ITC: 8.4% vs 14.6% % of homes with multiple DENV infections in humans: ITC vs Non ITC:

		Culex Quinquefasciatus DENV in Aedes by RT-PCR Bioassays Optimal use of curtain			29.4% vs 70.6% Overall ITC reduced intradomicilliary DENV transmission, ITC homes were significantly less likely to experience multiple DEN V infections than Non ITC Dengue virus-infected Aedes aegypti females were reduced within the ITC homes were curtain use was highest
Insecticide Treated Screens					
Manrique-Saide et al, 2015 (15)	Mexico, Acapulco	cRCT 5 months, 12, 18 and 24 months follow-up Adult surveys in 32 households from each cluster. Immatures surveys in 2000 households.	9 clusters: Insecticide treated screens (Duranet) Instalation in 586 households	10 clusters No treatment, existing routine vector control activies (adulticiding and larviciding) in response to elevated number	House infestation rates lower in intervention after 5 months (OR 0·38) and after 12 months (0·41). Presence–absence data (house infestation): 5 months vs 12 months:

	CI, HI, BI, PPI Mann-whitney non parametric, t-tests: differences between arms across the surveys Logistic regression models with a single predictor and (presence and absence) negative binomial models (count data)		of dengue cases and high entomological indexes.	Adult female mosquitoes: OR 0.38, (95% CI 0.21–0.69) vs OR 0.41, (95% CI 0.25–0.68) Blood-fed females: OR 0.36 (95% CI 0.21–0.60) vs OR 0.51 (95% CI 0.24–1.05). Males: OR 0.39 (95% CI 0.19–0.77) vs OR 0.41 (95% CI 0.27–0.64) Incidence rate ratios (Infestation density) 5 months vs 12 months Adult females IRR 0.37 (95% CI 0.27–0.49) vs IRR 0.40, 95% CI 0.23–0.70) males IRR 0.39 (95% CI 0.28–0.54) vs IRR 0.49 (95%CI 0.33–0.72)

					blood-fed females IRR 0.32 (95% CI 0.23–0.45) vs IRR 0.49 (95% CI 0.23–1.05) A comparison of wet season data from treatment houses before and after intervention showed that significantly fewer females and blood-fed females were found postintervention (Wilcoxon matched pairs W = 30706, z = 3.717, and W = 20706, z = 3.146; p<0.05 for both comparisons). However, the number of male mosquitoes did not change significantly (W = 20706, z = 1.385; p>0.05).
Che-Mendoza et al 2015 (16)	Mexico, Merida	cRCT 8, 13, 19, 25 months to 30 houses per cluster Indoor adult collections: BI, CI, HI, PPI	10 clusters (980 houses) 12 months of the study, treatment clusters received only	10 clusters (1000 households)	Presence absence data 18 months post-intervention: Adult females: OR=0.07, 95% CI: 0.05–0.10),

	WHO bioassays	LLIS. 14 months after installation: Spinosad for targeted containers Impact measured At 18 and 24 months, following introduction of TT at 14 months post-intervention.	blood-fed females: OR=0.63, 95% CI: 0.36–1.09) males: OR=1.19, 95% CI: 0.84–1.7) 24 months post-intervention: Adult females: OR=0.44, 95% CI: 0.20–0.95) blood-fed females (OR=0.28, 95% CI: 0.10–0.74) males (OR=0.44, 95% CI: 0.27–0.71) Infestation density based: 18 months post-intervention Adult females (IRR=0.12, 95% CI: 0.08–0.19) blood-fed females (IRR=0.54, 95% CI: 0.29–1.0 males (IRR=0.93, 95% CI: 0.72–1.22) 24 months post-intervention

	Adult females (IRR=0.04, 95% CI: 0.21–0.98) blood-fed females (IRR=0.25, 95% CI: 0.09–0.70) males (IRR=0.48, 95% CI: 0.27–0.86) At 18 months post-intervention numbers of houses positive for any developing stage (OR=0.44, 95% CI: 0.26–0.75) number of houses with larvae (OR=0.44, 95% CI: 0.26–0.75) number of larvae per house (IRR=0.36, 95% CI: 0.20–0.66) houses with pupae (OR=0.44, 95% CI: 0.23–0.82) number of pupae per house (IRR=0.22, 95% CI: 0.08–0.57) numbers of pupae per person (IRR=0.33, 95% CI: 0.13–0.82)

					At 24 months, post-intervention: number of larvae per house (IRR=0.33, 95% CI: 0.13–0.83) number of pupae per house (IRR=0.26, 95% CI: 0.10–0.68) number of pupae per person (IRR=0.30, 95% CI: 0.10–0.88)
Insecticide Treated Curtains and Insecticide Treated Container covers					
Overgaard et al, 2016 (17)	Colombia, Anapoima and La Mesa (rural)	2x2 Factorial cRCT At cluster level: Incidence rate of diarrheal disease, Adult index, BI, school index, number of pupil absence episodes	Diarrea interventions DIA: 9 shools: 231 students Dengue interventions DEN: 9 shools: 231 students	9 schools: 210 students No intervention	The mean density of adult female of *Aedes aegypti* were no significant between arms. BI: reduction 80%: DEN: 10.8 vs 46.9 DIA DEN: 6.25 vs 46.9 PPI: reduction of 94% but not significant PPI: 0.04 vs 0.36

	due to probable dengue and any illness, concentration of Eshcerichia coli in drinking water. ANCOVA Factorial analysis of covariance	Diarrea and dengue interventions DIADEN: 9 shools: 200 students DIA : targeting dinking water, sanitation and implementation of water filters, fitting lids or nets on all drinking water storage containers, cleaning of containers once per week. Educational component DEN: ITC (LifeNet) in classrooms and computer rooms and fitting lids or nets on all water containers,		School index: 10.5 vs 27.3 CI: 2.2 % vs 7.1% Schools with females: 31.6% vs 42.4% Mean between-arm rates of probable dengue: not significant differences Concentration of *E. coli:* CFU: significant lower in DIA and DENDIA arms. Lack of complete blockage of windows and doors, Material very light so breeze move them away, Quickly deterioration, Rural setting Importance of combing several vector control interventions targeting different stages of the mosquito life cycle

			for large containers pyriproxyfen once every 2 weeks. Larva source management during weekly solid waste clean-up campaign. Educational component DIADEN: lids or net on containers		
Quintero et al, 2015 (18)	Colombia, Girardot	cRCT 1 follow-up 9 weeks 8 follow-up 4-6 weeks after 1 follow-up BI, PPI Coverage, use and satisfaction Costs	10 clusters: 934 households: 922 curtains and 303 covers ITC and ITCC: PermaNet	10 clusters: 891 Routine dengue-related activities performed by the local health authorities	Curtains: baseline -1 follow (9 weeks) BI: 14 vs 6 vs 8 vs 5 PPI: 0.91 vs 0.93 vs 0.47 vs 0.31 Curtains plus covers: baseline -2 follow-up (29 weeks) BI: 14 vs 7.2 vs 8 vs 2.8 PPI: 0.91 vs 0.38 vs 0.47 vs 0.24 After 29 weeks, 45% of the households were using at least one curtain. Costs: curtains: 28.8 US$ and covers19.2 US$

					Acceptance can be achived by community participation Sustain effect will depend on multiple factors.
Rizzo et al, 2012 (19)	Guatemala, Poptun	cRCT with buffer zone 50- 100 meters 6 weeks after first intervention and 6 weeks after second intervention. t-test WHO bioassays:	10 clusters: 1000 houses ITC (PermaNet): 3079 ITCC 17 months after: 289 Temephos Routine activities: Temephos in 3 clusters	10 clusters: 1000 houses Routine activities: Temephos in 3 control clusters and	6 weeks after ITC: PPI 75% increased (rainy season) PPI: 0.84 vs 0.79 6 weeks after ITCC: PPI: -0.01 vs 0.52 Insecticide residual activity was high but with variability of chemical concentration. Acceptance high Increase observed during rainy season (containers found in public premises) Indexes raised in both intervention and control groups
Vanlerbergh e et al, 2011 (20)	Venezuela, Trujillo	Before after evaluation at: 6, 12, and 18 months BI, PPI	10 clusters: 7% of municipality houses: Urban areas: 560 houses	Rest of the municipality External control data:	At 18 months, less than 40% were using ITC and les than 20% ITCC. No differences between urban or suburban settings. Baseline vs 12 months follow up

	Urban and suburban areas	% difference between Pre post intervention Comparison between untreated areas Generalized linear random effect regression models with begative binomial rank :independent effect of coverage	Suburban: 560 houses ITC and ITCC for 150 - 200 Liter water storage jars (PermaNet) Maximun 5 curtains per house	emtonological data from Valera and Carvajal	Suburban: BI: 42.4 vs 3.8 PPI: 0.9 0.03 Urban: BI: 8.5 vs 15.8 PPI: 0.2 vs 0.2 Negative regression models: setting and rainfual was correlated to BI and PPI in interventions clusters for ITC The scale of the effect depend on household coverage Curtain usage declines rapidly due to pre-use behavior and contextual factors Deployment of ITC can result in reductons of *Ae. aegypti* when infestations are moderated but the magnitude of the effect depends on coverage attained

Kroeger et al, 2006 (21)	México, Veracruz Venezuela, Trujillo	cRCT 4 weeks, 4 months, 12 months Veracruz and 9 months Trujillo BI, CI, HI, PPI, Ovitraps: inside and outside households Serological surveys : recent dengue infection IgM (Trujillo) Attitudes towards the interventions Paired t tests	9 clusters: 61 houses (45-78 per cluster) Veracruz: Insecticide treated curtains (lambacyhalotrhin) and cloth bags with larval growth inhibitor Trujillo: insecticide treated curtains (Permanet) and insecticide treated water jar covers	9 clusters: 60 houses (47-83 per cluster) No intervention	Veracruz: Intervention vs control Baseline – 2 weeks follow up: BI: 60% vs 46% vs 113% vs 87% HI: 36% vs 19% vs 45% vs 30% Baseline – 12 months follow up: BI: 60% vs 7% vs 113% vs 12% HI: 36% vs 6% vs 45% vs 10% PPI: 3.4 vs 0.36 vs 2.0 vs 0.35 CI: 28% vs 11% vs 14% vs 2% Ovitrap index: 28% vs 11% Trujillo: intervention vs control Baseline – 12 months follow up: BI: 38% vs 11% vs 34% vs 17% HI: 19% vs 9% vs 19% vs 15% PPI: 2.7 vs 0.2 vs 1.6 vs 0.3 Ovitrap index: 33% vs 16% Prevalence IgM: Intervention vs control Baseline 16% vs 21% 8 months: 8% vs 18% High acceptance of curtains in both sites: over 87% High acceptance of covers: over 68%

		Clustering of house index: Ripleys K statistic			No differences between intervention and control groups Spill over effect at community level Covers not always used correctly Covers not durable and tore easily with contact use.
Insecticide treated container covers					
Kittayapong et al 2012 (22)	Chachoengsao, Tahiland	cRCT 2, 4 6 months follow-up BI, CI,HI, PPI	10 clusters Controlling immature stages: Mesocyclops aspericornis (copepods) and Bacillus thuringiensis var. israelensis toxins (Bti sacs). Household level: screen net covers (MosNetH) for water	10 clusters	Treatment vs control. 2 months follow-up PPI: 0.19 vs. 0.73 HI: 33 vs. 32 CI: 80.3 vs 9.24 BI: 71.22 vs 65.25 6 months follow-up: PPI 0.05 vs. 0.26 HI :11.68 vs. 14.03 CI: 3.01 vs5.38 BI: 24.46 vs 21.49

			jars, mosquito traps (MosHouseH) and portable vacuum aspirators (MosCatchTM)		Community-based dengue vector programme Raise awareness in applying cofiendly vector control approaches.
Tun-lin et al., (2009) (23)	Venezuela, Mexico, Peru, Kenya, Thailandia, Myanmar, Vietnam, Philippines	Venezuela, Trujillo cRCT 1 and 5 month follow-up	9 clusters : 80 houses per cluster ITCC for productive containers (PermaNet 2)	9 clusters: 80 houses per cluster Temephos plus rotine interventions in non-productive containers	Intervention vs control Baseline – 5 months follow up: BI: 11.2% vs 14.1% vs 6.6% vs 8.6% PPI: 0.61 vs 0.57 vs 0.23 vs 0.20 Non-significant differences Diff in Diff target vs non target vs control vs intervention: BI: 0.84 (95% CI -8.94 -10.62): indicates no difference PPI: -0.230 (-0.749 -0.703): indicates target intervention is more efficacious.
Systematic Literature Reviews					
Wilson et al, 2014 (24)		SLR and meta-analysis			The table published by Wilson et al in 2014 reports the efficacy of ITM in the control of different vector borne diseases.

	Nguyen 1996 Igarashi 1997 Dengue reduction: 81% (53%,92%,p<0.001)

ITN: Nets; ITC: curtains, ITS: screens, ITCC: container covers, PPI: pupae per person, HI: Household index, BI: Breteau Index, CI: container index, cRCT: cluster randomized controlled trial, RCT: randomized control trial

Appendix B. Literature review: Scaling-up vector borne interventions

For this review, I searched on Pubmed/Medline, database without any restriction on date of publication given the anticipated shortage of literature. The search was restricted to articles published in English or Spanish, with human subjects. The review considered a) any case study, descriptive study, intervention study or systematic review that b) analysed the scaling-up process of a vector borne intervention and c) described the approaches or models/frameworks associated with the scaling-up. Studies were excluded if full text was not available or if the article was not published. Experts in Latin America that have conducted evaluations of scale-up interventions for the control of *Aedes*-borne disease, Malaria and Chagas disease were contacted and asked for additional literature. Pubmed was accessed between June 15, 2017 and February 03 2020.

The terms included were: scalability, scaling-up, scale-up, scaled-up, scalable, expansion, expanding, expandable, expandability, institutionalization, institutionalisation, dissemination, disseminating and vector control interventions on dengue control or malaria control using the following formula: ((((((("lessons learnt") OR "evaluation studies as topic/methods") OR "process evaluation") AND "scaling up") OR "scale up interventions") AND ("vector control and prevention")) OR (("dengue vector control" OR "dengue vector control interventions" OR "dengue vector control program" OR "dengue vector control programme" OR "dengue vector control programmes" OR "dengue vector control programs"))) OR "malaria vector control" Information on scaling- up framework used, geographic setting, targeted population, disease and type of vector borne interventions and key factors were abstracted.

The search returned 603 articles and 16 articles after removal of duplicates were assessed. The review identified case studies from Africa, Asia and Latin America. Overall, 14 (88%) case studies described the challenges for scaling-up malaria control in Africa and Venezuela, 4 (17%) were related to dengue control and 2 (8%) to Chagas disease. All dengue and Chagas disease studies were conducted Latin America (Colombia, Cuba, Mexico, Honduras, El Salvador, Guatemala, Uruguay and Brazil). The majority of the research was related to the expansion (horizontal scaling-up) of long lasting insecticide treated nets for controlling malaria burden in Africa. There are few examples of analysis of the process of scaling-up interventions. The majority of the case studies report the strategy used for scaling-up (vertical or horizontal) rather than the framework followed to implement the process of scaling-up or for the analysis of the process.

Table B-1. Characteristics of studies reviewed reporting scaled up vector borne interventions

Author Year	Objective	a. Setting b. Intervention c. Disease d. Scaling-up approach	Methods	Results	
				Factors	Lessons
Fuentes-Vallejo et al, 2017 (25)	To identify and analyse the process of scaling up Ecohealth projects in six countries to determine the key elements for a successful scaling up of interventions.	a. Latin America: Guatemala (Olapa), El Salvador, (Texistepeque) Honduras (San Marcos de la sierra), Mexico (Merida and Acapulco), Colombia (Cali), Venezuela (Yekwana indigenous settlement) b**. Vector control**	**Study design:** Case study **Data collection**: Semi-structured interviews with 52 key stakeholders (researchers, beneficiaries, governmental	**Enabling:** - Innovation (the interventions implemented differ from the usual interventions in terms of content and management) - The interventions fulfil different purposes (results in quality life improvement)	Government participation can facilitate the process of scaling but when not possible the process can be led by other actors The scaling process requires the systematic use of evidence and

	-Malaria: Educational guidelines -Dengue: Mexico: Windows and doors insecticide screens Colombia: educational intervention for stakeholders - Chagas: house improvement and environmental management. c. Malaria, Chagas, and dengue	employees, and representatives of private sector) **Categories:** - Scaling-up strategies (innovation, management and financing, stakeholder participation - Factors influencing the process of scaling (urban and rural context, political context) - Results of the process of scaling (integrated	(multipurpose interventions) - Active community participation enhanced by different strategies - Diversity of financial resources - Inclusion of decision makers - Personal relations between researchers and decision makers - Interventions that include educational components are better adopted. - Innovation: Easy to install and understand **Limiting:**	monitoring bond to the process of decision making Avoid complex interventions or technologies that are difficult to understand or cannot be developed by tools or materials or implemented along within existing processes A management process Is always necessary. The intervention by itself does not produces a successful outcome

	d. Vertical and horizontal	interventions, changes among institutions and personnel involved, vertical scaling)	- Long term budget - Delays in resource allocation - Rural context: absence of adequate routes for access communities - Urban context: insecurity and violence this causes rejection to visits for intervention implementation	The emphasis in the participation and intersectoral work allowed the identification of changes in attitudes and comprehension of the vector borne diseases and the possibilities for their control.
			- Dengue only viewed as priority of the health sector - Municipality setting is the most appropriate setting for the developing of interventions - Lack of political will	The stakeholder closest to the projects reported the changes.

				- High turnover of personnel from public sector - Constant change in government - Difficulties for intersectoral collaboration - Lack of articulation between national policies and their local implementation -	
Chanda et al, 2016 (26)	To describe the approaches used to impact up vector control in Malawi, the challenges encountered, the lessons learnt	a. Africa: Malawi b. LLIN 2007 and indoor residual spraying 2010 c. Malaria	**Study design:** descriptive **Data collection:** not mentioned	**Enabling:** Not mentioned **Limiting:**	- In high-transmission impact, a single intervention approach for scaled-up malaria vector control may not have a

from this experience, and how these lessons have informed vector control efforts.	d. Horizontal	**Categories:** - Advocacy social mobilization and legislation - Collaboration within the health sector and with other sectors - Integrated approach - Evidence-based decision making - Capacity building	- Insecticide resistance - Community sensitization, participation, and ownership sporadic - Lack of technical capacity to deploy interventions - Inadequate technical design of commodities and equipment - Lack of consensus among stakeholder to use DDT - Suboptimal information sharing regarding entomological resources - Limited partner support - Lack of funds	substantial impact. - For optimal use of resources, a well-coordinated integrated vector management strategy may offer greater benefits. - For effective and sustainable vector control, an insecticide resistance monitoring and management plan involving all vector-control resources in the country is essential. - In Malawi, a functioning vector control needs adequate financial

				- Logistical problems: unpredictable and late disbursement of government funds	resources. - Scaling-up of vector control in similar settings will need to be carefully considered and adapted to the local situation in the context of the integrated vector management approach
Tesfazghi et al 2016 (27)	To investigate the factors influencing policy adoption and assess the role that actors and evidence play in the policymaking process, in order	a. Africa: Nigeria b. Larviciding c. Malaria d. Vertical scaling	**Study:** Retrospective policy analysis **Data collection**: In-depth interviews with national vector control policy or	**Enabling:** - Contribution to national economic development objectives through	- Care needs to be taken to ensure that evidence of effectiveness is also central to the policy process.

	to draw lessons that help accelerate the uptake of new methods for vector control.		strategy decision-making processes and compare these with the process that led to the decision to scale-up larviciding. A total of 14 national level stakeholders were interviewed: 3 policymakers, 1 researcher, 1 private sector representative, 4 multilateral agencies and 5 NGOs. **Categories:** - Context - Actors - Process - Content	larvicide production **Limiting:** - Decision involved a restricted range of policy actors, excluded actors that usually play advisory, consultative and evidence generation roles. - Powerful actors limited the access of some actors to the policy processes and content. - Donor pressure	- A greater focus on domestic economic benefits of malaria control could help generate domestic policy support and potentially finance for its control - Uptake or scale up of malaria control can be facilitated by linking malaria control objectives to wider economic considerations and through engaging powerful policy champions to drive policy change.

			- Power - Use of evidence	- Lack of engagement of national level politicians.	
Tesfazghi et al, 2016(28)	To identify potential challenges and opportunities for accelerating access to next-generation LLINs in Burkina Faso, a country with areas of high levels of insecticide resistance	a. Burkina Faso b. LLINs c. Malaria c. Vertical scaling	**Study design:** Case study **Data collection:** - Semi structured interviews - Desk review to identify key actors in vector control **Categories:**	**Enabling:** - Donors' willingness to finance - More independence from international funding in the form of allocation of national funds to malaria control - Strong track record of malaria vector control research with two	- The ability of research outputs to influence policy is felt as dependent on collaboration with international researchers. - National and global levels of policymaking are interlinked. - Access to next generation LLINs

	- Actors - Powers - Context, content, and process, - Availability - Affordability	international recognized research groups. - New funding model: direct up-front allocations, aligned to national strategic priorities. **Limiting:** - Price that limit availability - Different performances between types of nets - Low financial power of government - Lack of financial backing	is severely compromised by the lack of global guidance on where and when to deploy nets. - A clear WHO recommendation is the key to unlocking financial resources for and accelerating access.

				- Little control over net selection (Only Whopes recommended LLINs are permitted by donors) - Insecticide resistance - Absence of a clear recommendation of when and where to target next-generation LLIN	
Dambach et al, 2016(29)	To point out important steps in implementing an anti-malaria larviciding campaign in a resource an infrastructure	a. Burkina Faso: Sudano-Sahelian b. Larviciding champaign Bti c. Malaria	**Study:** Descriptive **Data collection:** - Perception and acceptability survey	**Enabling:** - Consultation and involvement of project stakeholders and national authorities.	- Close collaboration between research and political partners increases acceptance and facilitates promotion and ethical clearance

	restrain setting and share the lessons learned from the experience during three-year intervention study	d. Horizontal to 125 village	- Focus groups discussions **Categories:** - Project implementation - Budget requirements - Recruitment and motivation of staff - Community mobilization and acceptance - Project success and workflow improvements	- Co-construction and co-coordination of guidelines by national and international authorities - High project acceptance. **Limiting:** - Time constrains - Rural area did not facilitate timely meetings with all stakeholders at site	- Cultural and religious particularities were discussed with traditional believes and resolved during consultation. - The agreements required qualified personnel, high cultural sensitivity and several months of preparation.

				- Budget requirements exceed	
Mutero et al, 2015 (30)	To assess experiences and findings on Integrated vector management (IVM) in Kenya with a view of sharing lessons that might promote its wider application.	a. Africa Kenya: Malindi and Nyabondo b. IVM policy c. Malaria d. Vertical	**Study design:** qualitative external evaluation **Data collection:** - Institutional analysis: website review, documentary analysis, - interviews with project staff, community groups - direct observation	**Enabling:** - The initiation to start IVM is evidence based - Guidance by operational research - Media attention - Well-organized system of multistakeholder collaboration - advocacy and social mobilization	- A replication of IVM model would most likely require an effective national policy to promote and support the implementation of a multisectoral approach to malaria - The greatest need for continued engagement of government and

	- brainstorming retreat among researchers **Categories:** - **I**ntegration onto vector control methods - Evidence-based decision making - Intersectoral collaboration - Advocacy and social mobilization - Capacity building	- Community participation and empowerment - Urban and periurban area - Better resources - Transdisciplinary approach by combing expertise - Creating local networks - Beliefs: Mosquitoes nuisance of other species that do not transmit malaria encourage use. **Limiting:** - Expectations by the community to be paid for participating in project activities	international and national research agencies is perhaps in connection with long-term surveillance, monitoring and evaluation that are required using standard indicators for malaria IVM - Sustainability of IVM at community level depends on active participation by community-based groups and their collaborations with NGO,

				- Rural area	international and national research institutes, and various government ministries.
Chanda et al, 2014 (31)	To describe the approaches that first Southern Sudan and then South Sudan followed impact up LLIN coverage, the challenges encountered, the lessons learnt from this experience, and how these lessons have informed LLIN distribution.	a. Africa: South Sudan b. LLIN 2006 c. Malaria d. Horizontal	**Study design:** descriptive **Data collection:** not mentioned **Categories:** - Context: policy guidance, delivery mechanisms - Challenges - Lessons	**Enabling:** Not mentioned **Limiting:** Post conflict setting	- A phased and fragmented approach to the scale-up of a national campaign for the distribution of long-lasting insecticide-treated nets (LLINs) may not provide a good model for achieving universal bednet coverage in post-conflict settings.

		- Community sensitization and mobilization		- A nationwide campaign that is centrally coordinated and impact sound guidelines may offer greater benefits. - A strong partnership base and effective channels for the timely and supplementary deployment of LLINs may be essential if universal LLIN coverage is to be achieved.

Chanda et al, 2013 (32)	To report on strategies, achievements, and challenges if the past and contemporary malaria vector control efforts and to provide guidelines for future development of entomological interventions in the country.	a. Zambia b. Vector control in the context of IVM global strategic framework: Insecticide Residual Spraying (IRS), Long Lasting insecticide treated nets (LLIN), Larva source management (LSM) c. Malaria d. Horizontal	**Study design:** Case study, Retrospective analysis **Data collection:** - Analysis of routine surveillance data - Household surveys - Operations research reports. **Categories:** - Status in implementation policies and strategies	**Enabling:** - Strong national IEC/BCC campaigns through interpersonal and community –based approaches - Strengthen advocacy, social mobilization, and political leadership - Increase intersectoral collaboration and community involvement	- Significance of a coordinated multi-pronged IVM approach effectively operationalized within the context of a national health system - Strengthen collaboration leverage resources

		- Progress of programmatic implementation	
			- Monitoring and evaluation of interventions - Waive of taxes and traffic of nets has reduce the price **Limiting:** - Logistical challenges: inadequate transport and storage capacity at district level - Delays in disbursement if funds for IRS

- Low utilization of LLIN

- Lack of plan of disposal and replenishment

- Less efficacy and abuse of nets

- Not routinely collected national data regarding utilization of LLIN

- Limiting funding for LSM

- IEC campaigns are in conjunction with malaria commemorative day World Malaria Day.

- Spatial scale of collection on resistance

- Limit investment in entomological related capital equipment and infrastructure such as storage a facilities and laboratories.

- Lack of entomological capacity for optimal monitoring of interventions at

				provincial and district level. - Weak coordination and public-private sector involvement. - Inadequate funding by the government.	
Pérez et al, 2013 (33)	To describe and critically analyse the diffusion process of an effective empowerment strategy within the Cuban Aedes aegypti control program, focusing	a. Cuba b. Effective participatory strategies in dengue control c. Dengue	**Study design:** Process-oriented case study. **Data Collection:**	**Enabling:** - Perceived potential match between the innovative empowerment strategy and the performance gap of the Ae. Aegypti control program.	- Continuous and dynamic process of the diffusion of the empowerment strategy - Providing necessary knowledge about

on impact making at the national level, to identify ways forward to institutionalize such strategies in Cuba and elsewhere.	d. Vertical (institutionalize these strategies within dengue control programs)	- Participant observation - In-depth interviews with key informants involved in the diffusion process - Document analysis **Categories:** - Fidelity - Reinvention	- Partially modification by top level *Ae. Aegypti* control program makers to accommodate program characteristics. **Limiting:** - Insufficient dissemination of know-how and underlying principles of strategy by innovation developers	the innovation and addressing control programme organizational changes is crucial for successful diffusion of the strategy

				- Resistant to change	
Pérez et al, 2011 (34)	To understand what happened during implementation in view of improving the process To identify what reinventions were induced by implementers To understand difficulties and	a. Cuba: La Lisa b. Participatory strategy for dengue control with four components: organization & management, capacity-building, community work and surveillance c. Dengue d. Horizontal component to be integrated within the existing *Aedes aegypti* control program.	**Study design:** Process-oriented approach to assess fidelity and reinvention **Data collection:** - Participant observation - In-depth interviews with key informants involved in the diffusion process - Document analysis	**Enabling:** - Researchers played a very important role in conducting capacity- building and offering technical assistance. - Community capacity-building - Practical 'know-how' to implement	- Organizational change is central to this process. - Capacity-building seems to be easy to reproduce. However, this component requires well thought out approaches in order to motivate people to commit to be involved in and attend

	barriers faced during implementation To reveal information on the feasibility of implementing the strategy on a larger scale.		**Categories:** Fidelity and reinvention	the strategy **Limiting:** - Insufficient dissemination approach. - Weak resource mobilization.	workshops in different contexts. - The assessment methodology proposed by Rebchook et al. (2006), complemented by interviews which focus on the implementation process, proved useful in drawing lessons for the scaling-up and institutionalization of the innovative strategy, and enabled to assess reinvention concept. - At early stages of scaling-up, implementation

					still requires fine tuning and should be closely monitored. - Consider setting-up a monitoring system to identify additional needs at different levels and stages of implementation - In order to scale-up the strategy, the AaCP will require organizational capacity and competent staff to drive this community capacity-building.
Tambo et	To provide a.	SS Africa and	PR	**Study design:** Scoping	**Enabling:**	- Healthcare

al, 2012 (35)	synthetic information with scientific evidence of scaling up impact of malaria control interventions on the trends of malaria events from 1960 to 2011, to help stakeholders, and policy-makers to take informed decisions on public health issues and intervention designs on malaria control towards elimination	China b. Malaria control (ITN, LLIN, IPTp, ACTs strengthening health system) c. Malaria d. Vertical and horizontal	review for articles published from January 1960 to December 2011 **Databases:** PubMed/MED- LINE (OVID), Embase, Web of Knowledge, Scopus, and the WHO's WHOLIS and regional office databases. **Terms:** interventions, epidemiological studies on malaria trends	- Translations of national policy into innovative control strategies are imperative in strengthening the healthcare systems and actions - Political commitment and financial potentials - Effective delivery operations at national, provincial and district levels - Capacity in monitoring vector-related and operational factors - Health systems with: a good leadership and	systems with efficient National Malaria Control Programmes that have adequate national and global support on malaria control using integrated strategy, including existing early diagnosis and prompt treatment, combined with vector control, have shown a significant n reducing malaria morbidity and mortality rates. - Delivery strategies need to be adapted to existing control programs and

		governance, clear definition of policy and financing frameworks, to coordinate all partners; sustainable financing and social protection through accessibility to adequate and timely resources, efficient and cost effective for malaria prevention and control, timely and reliable health information dissemination as well as monitoring and evaluation - Functional partnerships between	integrated with other disease and development programs systems to enable malaria control, scaling up and maintaining universal coverage. - Particular attention is required to ensure that control interventions reach the most vulnerable populations, and that gender, socio-economic status or geographic location are not

	government and other key stakeholders (the academic and educational sector, non-government and community-based organizations, private sector, religious and faith-based organizations; and multi-/bilateral development partners) **Limiting:** - Lack of political commitment - Inadequate management - Lack of	barriers to accessibility, availability, and affordability. - Our findings showed that there is a crucial need for capacity building to the district and local level and outside the traditional malaria system.

		infrastructure in rural (difficult accessibility and availability of drugs, as lack of qualified medical personnel) - Collision between the vicious cycle of malaria and poverty - Insecticide resistance, especially pyrethroid resistance - Inefficient health systems, healthcare service coverage and delivery systems, and drug shortage, counter prescriptions, self-medication - Overstretched	

				health systems	
Masum et al, 2010 (36)	To summarize the history and current status of A to Z textils and analyse the factors that led to this success. To suggest policy considerations that could further support similar procedures of health goods in low income setting in the future.	a. Tanzania b. A to Z textiles: largest bed net manufacturer c. Malaria d. Horizonal	**Study type**: case study **Data collection:** - Semi-structured interviews with key informants familiar with A to Z textiles. - Related articles from peer review literature, news reports from WHO **Categories:** - Roles played by funding and employment - Scaling up manufacturing and partnership	**Enabling:** - Strong partnership with other companies that provided the technology and financial support - Strengths in distribution and local manufacturing - Bring organizations with complementary capacities - Channels of distribution: private distribution	- Supportive partnership can mobilize the capacity to tackle own health challenges - Relationships can provide incentives and de risking for the private sector in the developing world to engage in innovation - Increase investment in R&D including adding laboratory facilities and local scientific talent. - Importance of

	- Regulatory issues affecting viability of production - Factors influencing ability and pricing	network, mobile distribution, for public sector buyers. - Responsiveness to opportunities - Willingness to invest and take risks - Ability to execute - Strong leadership - Consistent commitment to the endeavour - Donor funding creates demands - Capacity building - Local employment **Limiting:** - Full certification are supported by greater evidence	integrated view of innovation covering technical, business, and social aspects. - Health products can be developed by leveraging existing strengths in low resource settings. - Local funding, scaling up manufacturing, technology transfer and partnership, perceived benefits, local employment and capacity building all play important roles

				based from trials needs more investment - Prospect of market saturation - Absence of the private Enterprise - Regulatory issues - Procurement rules	
Cliff et al, 2010 (37)	To describe recent policy development regarding their use in Mozambique, South Africa and Zimbabwe.	a. Mozambiquin South Africa, Zimbabwe. b. Vector management c. Malaria d. Vertical (Policy development)	**Study type**: Qualitative case study **Data collection**: key informant interviews, document reviews, timeline of key events	**Enabling:** - Local ownership - Motivation of key stakeholders - Overwhelming benefits of intervention **Limiting:** - ITN distribution by	- Policy makers needs more evidence from RCTs to convince them to change policies that they consider work and have used for years - Avoid taking sides is fundamental to evidence-based policy making.

			Categories: - Factors influencing policy development up divided by interests, ideas and events	NGOs: government policy makers are reluctant to embrace an intervention that they do not control - Intervention requiring creating new infrastructure and complex logistic	- Those intending to promote new policies such as ITN should examine the interest and ideas motivating stakeholders and their institutions. - Identify where shifts or coalitions among the likeminded are possible
Woelk et al, 2009 (38)	To explore the policy making process of two cases: magnesium sulphate in treatment of eclampsia in pregnancy (clinical case) and	a. Mozambique, South Africa, Zimbabwe b. ITN and indoor residual household spraying c. Malaria	**Study type**: qualitative case-study **Data collection:** - Document review	**Enabling:** - Lobby groups and champions - Small number of health care researchers, policy makers and	- There is openness among policy stakeholders to consider research findings. - Local champions are important and

	the use of ITN and indoor residual household spraying for malaria vector control (public health case) Explores the perceptions of stakeholders involved in research and policy making	d. Vertical (upstream policy making process)	- Key informant interviews - Timelines **Categories:** Evidence uptake in the policy making process research evidence involvement of local researchers Prior clinical or public health experience Research and policy champions	institutions produce greater interaction between them and contribute to the movement of researchers to policy domains - Quality of research **Limiting:** - Political factors: Local conflicts - Wider array of stakeholders resembles issue networks - Knowledge translation dependant on few key people	are the potential route for facilitating knowledge transfer - Networks can have both negative and positive impact - Context is an important filter for the translation of knowledge at local levels. Strong international evidence may therefore not be always locally accepted. - Capacity for absorption was limited by human and other resource constrains

			International networks	- Bureaucratic processes (power and budget struggles and conflicts) - Skills and attitudes of those receiving the research - Interaction and trust between stakeholders	
Chanda et al, 2008 (39)	To report on IVM processes, achievements, and the status of key elements if IVM over the past five years	a. Zambia b. IVM strategy c. Malaria d. Vertical and Expansion (horizontal)	**Study type**: qualitative case-study **Data collection**: **Categories:** IVM	**Enabling:** - Development of a national malaria strategic plan (policy, partnership, equity, strength health system, evaluation of evidence based and cost-effective package)	- Enhance advocacy social mobilization and availability of legislation has greatly stimulated community awareness, culminating into community participation in the delivery of kye

	- Advocacy, social mobilization, and legislation	- Suitable legal and regulatory policy framework - Prioritization of malaria within the basic health care package - Declaration of malaria as a public health problem in the national strategic plan - Removal of takes and tariffs for ITN and insecticides - Enhance community participation	preventive interventions. - Availability of IVM structures at district level has enable the districts to plan budget and produced annual reports on IVM activities - The establishment of IVM working group facilitated the development of the country specific IVM guidelines information education and communication

materials and intersectoral collaboration with several partners

- Spray operators are selected based on eligibility criteria that include minimum academic qualification

- All options of inter and intersectoral collaboration

- Strong adherence to principals of subsidiarity in planning and decision making

- Establishment of IVM committee

- The strategy has also created a platform to address broad policy and regulatory issues and leveraged additional resources

- Decision evidence based

- Definition of indicators and tools for monitoring using WHO guidelines

- Capacity building: development of a vector control unit with postgraduate level staff

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Appendix C. Information and communication materials

Table C-1. Information and communication materials

Material	Description	Target audience	
Three bulletins or newsletters	Short statements of news about project activities and general health recommendations. The document was divided into 5 sections: Project progress; Voice from the community; VBD prevention and control measures; general health recommendations; and future project activities.	Community members and key partners	

Boletín

No. 2 • Septiembre de 2016

Girardot, destino turístico, amable y libre de enfermedades transmitidas por el *Aedes aegypti.*

Girardot destino turístico y amable

¿Qué está pasando?

Acciones que nos hacen avanzar

El pasado mes de agosto, se llevó a cabo el Octavo Comité Intersectorial en el auditorio de la Universidad Nacional Abierta y a Distancia (UNAD) de la Ciudad de Girardot, el cual tiene como objetivo apoyar en la reducción de la carga de las Enfermedades Transmitidas por Vectores – ETV, que afectan al municipio generando discapacidad, mortalidad y morbilidad en sus ciudadanos.

En el marco de los acuerdos instaurados el pasado 27 de mayo el Doctor Manuel Díaz, Secretario de Salud de Girardot, presentó los avances de la propuesta que busca darle continuidad y sostenibilidad al Comité Intersectorial. Para ello, se expuso el documento "Proyecto de Acuerdo Municipal", el cual plantea dar legitimidad jurídica al espacio que se ha generado a partir de la iniciativa y apuesta que hace el municipio por un ***"Girardot, destino turístico y amable libre de Aedes aegypti"***. Se espera que antes de finalizar el año, el proyecto de acuerdo este radicado y pueda pasar a revisión y aprobación por parte de la Corporación del Concejo Municipal y firma del Alcalde.

Presentación de iniciativa de Mural informativo acerca del control del vector *Aedes aegypti* para Colegios del municipio, por parte del Instituto Kennedy.

Con lo anterior el Comité Intersectorial dirigido por la Secretaría de Salud de Girardot, en cabeza del Doctor Manuel Díaz, y el acompañamiento de las instituciones públicas, privadas y diferentes representantes de la sociedad civil, se podrá institucionalizar un espacio participativo de debate en el municipio donde se tracen acciones conjuntas para mejorar la salud y bienestar de las comunidades.

Durante este comité también se presentaron los proyectos piloto que se vienen desarrollando en conjunto con dos colegios del municipio.

1

Two brochures	Including critical information about the details of the intervention and products and services provided by the project.	Key partners: national, regional, and local authorities from different sectors.	

461 almanacs	Annual publication listing a set of current information about dengue and vector control activities developed in conjunction by research team and State Secretariat of Health	Household members	

<table>
<tr>
<td>1580 information sheets (“tapa y lava la tapa”)</td>
<td>Providing information about proper use and care of covers.</td>
<td>Household members</td>
<td>
</td>
</tr>
<tr>
<td>40,000 Flyers</td>
<td>Providing information about recommendations for Aedes related diseases prevention and control measures</td>
<td>Tourists at hotels and land transport terminals.</td>
<td>
</td>
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</table>

28 Posters	Printed sheets containing information about project activities, number of covers installed and contact data, posted in public spaces of study sector neighbourhoods	Community members	

		
1 School banner	Teachers, parents, and students from Instituto Kennedy	

Appendix C2: Images A to I. Types of water containers lids

Image A

Image B

Image C

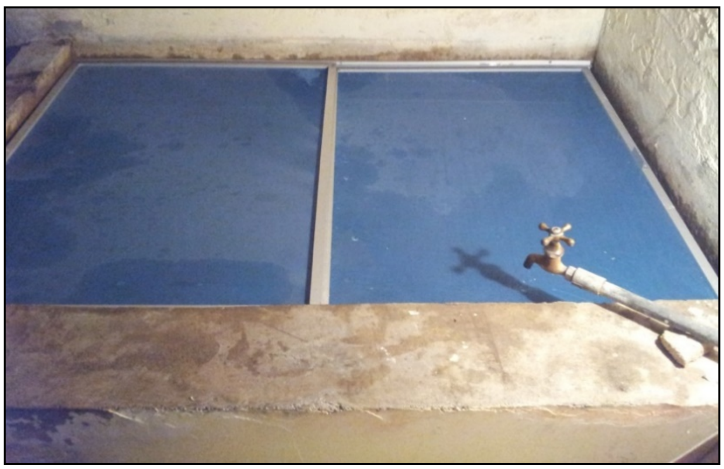

Image D

Image E

Image F

Image G

Image H

Image I

Appendix D. Effectiveness of the intervention in household and public space: Surveys and supplementary information

Appendix D1. Acceptability survey

	FUNDACIÓN SANTA FE DE BOGOTÁ EJE DE SALUD PÚBLICA Encuesta de seguimiento a intervenciones en viviendas	Versión 2. Fecha: 05/01/2017 Elaborado por: HR, TG Revisado por: HR, TG, JQ

I. Información básica del hogar y la vivienda

1. Fecha de Visita: DD / MM / AAAA
2. Hora de Inicio Encuesta: ___ : ___ ☐ AM ☐ PM
3. Sector No
4. Zona: ☐ Intervención ☐ Control
5. Número de Caracol
6. Manzana de campo No
7. Código de la vivienda
8. Departamento:
9. Municipio:
10. Barrio:
11. Dirección:
12. Teléfono:
13. Celular:
14. Tipo de visita ☐ Seguimiento 1 ☐ Seguimiento 2 ☐ Seguimiento 3
15. Posee tapa o cobertor instalados ☐ 1 = SI ☐ 2 = NO
16. ¿Cuántas personas viven en esta vivienda actualmente incluyéndose a usted?
17. ¿Cuántos hogares tiene la vivienda?
18. ¿Cuántas personas viven en su hogar?
19. Tipo de Vivienda ☐ 1 = Casa ☐ 2 = Apartamento ☐ 3 = Cuarto(s) en inquilinato ☐ 4 = Cuarto(s) en otro tipo de estructura ☐ 5 = Otro tipo de vivienda (carpa, tienda, vagón, embarcación, refugio natural, puente, etc.)
20. ¿Hace cuánto vive en esta vivienda?
21. ¿Antes donde vivía(n)? ☐ 1= Siempre hemos vivido en el mismo lugar ☐ 2= Mismo municipio, diferente barrio ☐ 3= Diferente municipio, mismo departamento ☐ 4= Diferente departamento ☐ 5= Mismo Barrio diferente casa. ☐ 6= Otro país. Si aplica. ¿Cuál es el lugar donde vivía anteriormente?
Departamento: Municipio:
Barrio: Dirección:
22. ¿Cuántos pisos tiene su vivienda?
23. ¿Cuántos días por semana permanece habitada esta vivienda?

II. Acciones realizadas por las entidades públicas.

24. ¿Hace cuánto recibió la última visita de un técnico de vectores? ☐ 1= En el último mes ☐ 2= Hace 2 o 6 meses ☐ 3= Hace 7 a 12 meses ☐ 4= Hace más de 1 año ☐ 5= Nunca ☐ 6=No sabe / No se acuerda
25. En la última visita, ¿le dieron alguna instrucción o información sobre cómo evitar la reproducción del mosquito? ☐ 1 = SI ¿Cuál? ☐ 2 = NO ☐ 3 = No sabe / No se acuerda
26. ¿En la última visita le dieron algún elemento o producto para controlar el mosquito? ☐ 1 = SI ¿Cuál? ☐ 2 = NO ☐ 3 = No sabe / No se acuerda
27. ¿Alguna vez ha recibido instrucciones o materiales para prevenir el dengue, el chikungunya o el zika? (Ej. material impreso, químicos, control biológico) ☐ 1 = SI ¿Cuál? ☐ 2 = NO ☐ 3 = No sabe / No se acuerda
28. ¿Qué información le gustaría que le ampliaran sobre el dengue, chikungunya y zika? ☐ 1. Como se transmite ☐ 2. Como se previene ☐ 3. Como se controla ☐ 4. Signos y síntomas ☐ 5. Otra ¿Cuál?
29. ¿En el último mes la Secretaria de Salud ha pasado fumigando su casa o el barrio? ☐ 0 = NO ☐ 1 = SI → Sabe usted ¿Hace cuántos días? ☐ 0= No sabe/No recuerda ☐ 1=Si → ¿Cuántos?
30. ¿Cómo fue la fumigación? ☐ 1=Vehículo ☐ 2=Motomochila ☐ 3 = No sabe / No responde

III. Prácticas en Dengue, chikungunya, zika y el Vector

31. ¿Qué hace usted en casa para reducir la incomodidad ocasionada por los mosquitos?
☐ 1 = Nada
☐ 2 = Fumigación al interior de la casa → ¿Cada cuánto? ☐ 1 = Todos los días ☐ 2 = una vez por semana ☐ 3 = Día de por medio ☐ 4 = Cada semana ☐ 5 = Cada 15 días ☐ 6 = Cada mes ☐ 7 = Mas del mes ☐ 8 = No sabe / No responde
☐ 3 = Limpieza de basura ☐ 4 = Cubrimiento de depósitos de agua
☐ 5 = Agrega químicos en el agua → ¿Cuáles? ¿Cada cuánto? ☐ 1 = Todos los días ☐ 2 = una vez por semana ☐ 3 = Día de por medio ☐ 4 = Cada semana ☐ 5 = Cada 15 días ☐ 6 = Cada mes ☐ 7 = Mas del mes ☐ 8 = No sabe / No responde
☐ 6 = Tiene animales en el agua (peces, tortugas)

III. Prácticas en Dengue, chikungunya, zika y el Vector

31. ¿Qué hace usted en casa para reducir la incomodidad ocasionada por los mosquitos?

☐ 7 = Matar mosquitos, por ej., con químicos, plaquitas o bobina de mosquito → ☐ 1 = Líquido ☐ 2 = Aerosol ☐ 3 = Plaquitas ☐ 4 = Espiral ☐ 5 = Otro ¿Cuál? ________________

¿Cada cuánto? ☐ 1 = Todos los días ☐ 2 = una vez por semana ☐ 3 = Día de por medio ☐ 4 = Cada semana ☐ 5 = Cada 15 días ☐ 6 = Cada mes ☐ 7 = Mas del mes ☐ 8 = No sabe

☐ 8 = Protección personal con repelentes (Si esta opción es seleccionada. Escriba el repelente que utiliza, y la frecuencia de uso en horas) → Nombre de repelente ________ Frecuencia de uso en horas ________

☐ 9 = Uso de angeos o toldillos ☐ 10 = Educa a otros miembros de la familia y/o vecinos sobre las medidas para disminuir los mosquitos ☐ 11 = Otros ¿Cuál(es)? ________

32. ¿Cuáles de estas medidas de control considera efectivas?

☐1. Cambiar el agua de los tanques ☐2. Limpiar los tanques ☐3. Utilizar tapas para los tanques ☐ 4. Tapar pozos u otros recipientes con agua
☐ 5. Usar insecticidas ☐ 6. Poner peces en tanques ☐ 7. Cortinas para camas ☐ 8. Cortinas con insecticida
☐ 9. Colocar angeo en puertas y ventanas ☐ 10. Aplicarse repelente ☐ 11. Aplicar cloro a los tanques ☐ 12. Colocar químicos en el agua
☐ 13. Otro ¿Cuál? ________

IV. Seguimiento a las medidas de intervención. Cobertores

33. Número de tanques redondos en la vivienda ________

34. ¿La vivienda tiene cobertor para los tanques redondos? ☐ 1 – SI ☐ 2 – NO **(pase a la pregunta 37)**

35. ¿Cuántos cobertores se instalaron en los tanques redondos? ________

36. El cobertor posee algún daño ☐ 1 = SI ☐ 2 = NO → ¿Cuáles? ☐ 1= Quemada ☐ 2=Descosida ☐ 3=Cortada ☐ 4=Agujero o rasgón mayor a 5 cm ☐ 99=Otro ¿Cuál? ________

V. Seguimiento a las medidas de intervención. Tapas

37. Número de albercas en la vivienda ________

38. ¿La vivienda tiene instalada(s) tapa(s) del proyecto? ☐ 1 – SI ☐ 2 – NO **(pase a la pregunta 74 si tiene cortinas, o 83 si no tiene cortinas)**

39. ¿Cuántos tapas se instalaron en las Albercas? ________

	Alberca 1		**Alberca 2**	
40. ¿Cuál es el tipo de sistema de cerrado instalado en las albercas?	☐ 1 – Colocar ☐ 2 – Deslizable ☐ 3 – Plegable ☐ 4 – Abertura lateral		☐ 1 – Colocar ☐ 2 – Deslizable ☐ 3 – Plegable ☐ 4 – Abertura lateral	
	Tipo de hojas que conforman la tapa	**Hojas de la tapa que poseen algún daño**	**Tipo de hojas que conforman la tapa**	**Hojas de la tapa que posee algún daño**
41. ¿Cuál es el tipo de hojas de la tapa instalada en la alberca?	☐ 1 – Superpuesta ☐ 2 – Deslizable fija entre rieles ☐ 3 – Deslizable removible ☐ 4 – Plegable con bisagras ☐ 5 – Fija con bisagras ☐ 6 - Fija	1 - ☐ 2 - ☐ 3 - ☐ 4 - ☐ 5 - ☐ 6 - ☐	☐ 1 – Superpuesta ☐ 2 – Deslizable fija entre rieles ☐ 3 – Deslizable removible ☐ 4 – Plegable con bisagras ☐ 5 – Fija con bisagras ☐ 6 - Fija	1 - ☐ 2 - ☐ 3 - ☐ 4 - ☐ 5 - ☐ 6 - ☐

42. Observación del estado de las tapas instaladas

	Seleccione los materiales donde observa daños	Unidad de medida	Cantidad	Describa o marque el tipo de daño observado
	Tornillos	Unidades		
	Riel(es) Perfil U	Longitud (cm)		
	Riel(es) Perfil tubular	Longitud (cm)		
	Riel(es) Angulo	Longitud (cm)		
	Bisagras	Unidades		
	Remaches	Unidades		
	Manija	Longitud (cm)		
	Malla impregnada con insecticida	Número de huecos		☐ *1= Quemada* ☐ *2=Descosida* ☐ *3=Cortada* ☐ *4= Agujero o rasgón mayor a 5 cm* ☐ *99=Otro ¿Cuál?*
	Empaque perfil mosquetero	Longitud (cm)		
	Marco (Perfil mosquetero)	Longitud (cm)		
	Otro(s) ¿Cuál(es)?			

VI. Modificaciones posteriores a la instalación realizadas por el usuario	☐ Alberca 1	☐ Alberca 2	☐ Cobertor 1	☐ Cobertor 2	
43. ¿Dónde se encuentra la tapa o el cobertor? *1 = Adentro 2 = Fuera*					
44. ¿La tapa o cobertor se encuentra bajo techo? *0 = No 1 = Sí*					
45. ¿La tapa o cobertor se encuentra debajo de algún elemento que pueda caer sobre ella? *0 = No 1 = Sí*					
46. ¿Ha realizado alguna reparación? *0 = No 1 = Sí 3 = NS / NR*					Si "NO" pase a pregunta 50
Si es "Sí" Especifique ¿Cuál?					
47. Aproximadamente ¿Cuál fue el valor de la reparación? *En caso de no saber o no recordar diligencie NS/NR*					
48. ¿Al cuánto tiempo realizó la reparación? *Escriba un número seguido de una letra "d", "m", "a" o NS/NR según corresponda. d = días m = meses a = años NS/NR = No sabe / No se acuerda*					
49. ¿Quién realizó la reparación?					
50. ¿Usted usa la tapa o el cobertor? *0 = No 1 = Sí*					Si "SI" pase a la 52
51. ¿Por qué no lo está utilizando? *1= Mal diseño 2=Incomodidad 3= Alergia 4= Se dañó 99=Otro*					
Si es "Otro" Especifique ¿Cuál?					
52. ¿En algún momento del día la tapa está expuesta directamente a los rayos del sol? *0=No 1=Sí*					
53. ¿Alguna vez ha lavado la tapa o el cobertor? *0=No 1=Sí*					Si "NO" pase a 57
54. ¿Cuantas veces los ha lavado?					
55. ¿Cuál fue la marca del jabón o detergente utilizado?					
56. ¿Cómo secó le tapa? *1 = Directamente bajo el sol 2 = Parcialmente bajo el sol 3 = Bajo la sombra 99 = Otro*					
Si es "Otro" Especifique ¿Cuál?					
57. ¿Qué tan limpia está la tapa o el cobertor? 1=Limpia 2=Medio limpia 3=Sucia					
58. ¿Qué cambios ha percibido referente al depósito desde que se puso la tapa o cobertor? *1=Sin mugre 2=Con más mugre 3=Menos larvas 4=Mas larvas 5=Menos pupas 6=Mas pupas 7=Se murieron los peces o animales que estaban en el depósito 99=Otro*					
Si es "Otro" Especifique ¿Cuál?					

VII. Percepciones sobre el uso de tapa tanques

59. ¿Está satisfecho/a con la manera en que se le entregaron las tapa tanque del proyecto? ☐ 1 = SI ☐ 2 = NO → Si es "No" ¿Por qué? ______

60. ¿Cómo considera la calidad del material de las tapa tanque? ☐ 1= Bueno ☐ 2 = Regular ☐ 3 = Malo Si es "Regular" o "Malo" responda, ¿Por qué? ______

61. ¿Si las tapas fueran vendidas en el mercado, usted estaría dispuest@ a comprarlas? ☐1 = SI ☐ 2 = NO → Si es "No" ¿Por qué? ______

62. ¿Recomendaría la utilización de las tapas con insecticida de larga duración? ☐ 1 = SI ☐ 2 = NO → Si es "No" ¿Por qué? ______

63. ¿Ha observado alguna diferencia en la presencia de zancudos, larvas o pupas en el depósito u otros desechos con la instalación de las tapas del proyecto? ☐ 1 = SI ☐ 2 = NO

64. ¿Ha disminuido la compra de insecticida (raid, plaquetas, etc.) desde la instalación de las cortinas y las tapas? ☐ 1 = SI → Si es "Sí" ¿Cuánto dinero ha dejado de gastar? ______ ☐ 2 = NO

65. Desde la instalación de las tapas o cobertores ¿usted o algún miembro de su familia ha presentado dengue, chikungunya o zika? ☐ 1 = SI ☐ 2 = NO

Si es "SI". Diligencie el cuadro de la sección VIII (pregunta 66) quiénes son los miembros de la familia que presentaron la enfermedad. Si es "No" Pase a pregunta 74
Si la familia es nueva en la vivienda, deje para el final el diligenciamiento de la sección XI (Pregunta 112) donde se registran los miembros de nuevos hogares en viviendas donde ya se realizó intervención.

66. ¿Está satisfecho/a con la tapa tanque / Cobertor instalado?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "No" ¿Por qué?
67. ¿Existió algún problema con la instalación?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "SI" responda, ¿Cuáles?
68. ¿La tapa ha estado en contacto con animales?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "SI" ¿Cuáles?
69. ¿Ha visto usted que a la tapa le coloquen elementos pesados encima?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "SI" ¿Cuáles?
70. ¿Quién manipula la tapa / Cobertor?	☐ 1 – Ama de casa ☐ 2 – Niños ☐ 3 – Personal de servicio ☐ 4 – Adulto Mayor ☐5 – NS / NR ☐ 6 – Otros	Si es "Otros" ¿Quiénes?
71. ¿Es fácil el uso de la tapa / cobertor?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "NO" ¿Por qué?
72. ¿Es fácil limpiar la alberca / tanque?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "NO" ¿Por qué?
73. ¿Es fácil abrir y cerrar la tapa / quitar el cobertor?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR	Si es "NO" ¿Por qué?
74. ¿Es fácil abrir colocar una manguera?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR ☐ 4 = NA	Si es "NO" ¿Por qué?
75. ¿Es fácil lavar ropa o utensilios del hogar?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR ☐ 4 = NA	Si es "NO" ¿Por qué?
76. ¿Qué tanto permanece la tapa abierta?	☐ 1 – Todo el día ☐ 2 – Solo cuando se lava ☐ 3 – A veces ☐ 4 – Otra ☐5 – NS / NR	Si es "Otro" ¿Cuánto? Trate de especificar número de veces y momentos en unidades de tiempo
77. ¿Le cambiaría o mejoraría algo a la tapa?	☐ 1 = SI ☐ 2 = NO ☐ 3 = NS / NR ☐ 4 = NA	Si es "NO", pase a pregunta XX
78. ¿Qué cambiaría o mejoraría de la tapa?	☐ 1 – Materiales del marco de la malla ☐ 2 – Material ☐ 3 – Apertura de la tapa ☐ 4 – Diseño para abrir la tapa ☐5 – NS / NR	Si es "Diseño para abrir la tapa" Especifique que cambios realizaría

VIII. Casos de Dengue, Chikungunya y zika (En caso de ser mayor el número de miembros de la familia que han presentado casos después de la instalación diligencie la hoja anexa)

Miembro de del hogar No	79. Nombres y Apellidos	80. Parentesco con el jefe del Hogar 1 = Jefe del hogar 2 = Padre 3 = Madre 4 = Cónyuge / Compañer@ 5 = Hij@ 6 = Hij@ no biológico 7 = Ti@ 8 = Abuel@ 9 = Otro familiar 10 = No pariente	81. ¿Cuantos años cumplidos tiene? (infante=0)	**Desde la instalación de las tapas o cobertores…** ¿Cuántas veces ha padecido la enfermedad? ¿Ha sido diagnosticada por un médico?						85. ¿Cuándo fue la última vez que estuvieron enfermos por dengue, chikungunya o zika? 1= Últimos 15 días 2= Hace un mes 3= Hace más de 1 mes 4= No sabe			86. En esa última vez. ¿Dónde consultó inicialmente cuando comenzó la enfermedad? 1= Droguería o farmacia 2= Vecina/o 3 = Familiar 4 = Centro de Salud 5= Hospital 6= Médico particular 7= Curandero o chaman 8 = No consultó
				82. DEN		83. CHI		84. ZIK					
				No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	DEN	CHI	ZIK	
1					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
2					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
3					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
4					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				

87. Desde la instalación de las tapas, cortinas o cobertores ¿usted o algún miembro de su familia ha presentado alguna reacción, alergia u otro tipo de reacción a alguno de sus materiales? ☐ 1 = SI ☐ 2 = NO

Si es "SI". Diligencie el cuadro de la sección IX (pregunta 88) quiénes son los miembros de la familia que presentaron la enfermedad. Si es "No" Pase a pregunta 96

IX. Eventos adversos (En caso de ser mayor el número de miembros de la familia que han presentado reacciones o alergias después de la instalación, diligencie la hoja anexa)

Miembro del hogar No	88. Nombre y Apellido del miembro del hogar que presentó el evento	89. Parentesco con el jefe del Hogar 1 = Jefe del hogar 2 = Padre 3 = Madre 4 = Cónyuge / Compañer@ 5 = Hij@ 6 = Hij@ no biológico 7 = Ti@ 8 = Abuel@ 9 = Otro familiar 10 = No pariente	90. Edad	91. Fecha en que inicio el evento	92. Describa el tipo de reacción que presentó	93. En esa última vez. ¿Dónde consultó inicialmente cuando comenzó la enfermedad?		94. ¿Recibió diagnóstico médico? *0 = No 1 = Si ¿Cuál?* 3 = No sabe / No se acuerda	95. ¿Recibió tratamiento médico? *0 = No 1 = Si ¿Cuál?* 3 = No sabe / No se acuerda
						Lugar 0=No acudió 1=Clinica Dumian 2=Clínica San Sebastián 3=Clínica de Especialistas 99=Otro ¿Cuál?	Fecha en que acudió al servicio de salud		
1				DD/MM/AA			DD/MM/AA		

96. ¿Tiene cortinas o angeos impregnados con insecticida de larga duración en su vivienda? ☐ 1 = SI ☐ 2 = NO

Si es "SI". Pase a la sección X (pregunta 97). Si es "No" la encuesta ha finalizado

Hora de Finalización: ______: ______ ☐ AM ☐ PM Nombre de Encuestador: ________________________________ Firma de Coordinadora: ______________________

X. Seguimiento a las medidas de intervención. Cortinas

97. ¿Cuántas cortinas o angeos impregnados con insecticida de larga duración en su vivienda?

Aspecto a observar de las cortinas	CORTINA 1	CORTINA 2	CORTINA 3	CORTINA 4	CORTINA 5	
98. Desea realizar la seguimiento a la cortina instalada en: *1=Puerta 2=Ventana*						
99. ¿En qué lugar de la casa se encuentra instalada? *1 =Habitación principal, 2= Habitación 2, 3=Habitación 3, 4=Habitación 4, 5=Cocina, 6=Sala, 7=Comedor, 8=Estudio, 9=Baños, 10=Garaje, 11=Patio, 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
100. ¿Dónde se encuentra la cortina? *1=Adentro 2=Fuera*						
101. En relación a otra cortina convencional sin insecticida: *0=No hay cortinas convencionales, 1=Se encuentra por delante, hacia la ventana* *2=Se encuentra por detrás*						
102. ¿Usted usa la cortina? *0=No 1=Sí*						Si "Sí" pase a 91
103. ¿Por qué no está utilizando las cortinas que recibió? *1= Mal diseño 2=Incomodidad 3=Alergia* *4= Se dañó 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
104. ¿Observa algún daño en las cortinas instaladas por el proyecto? *0=No 1=Sí*						Si "No" pase a 93
105. ¿Qué tipo de daño observa? *1= Quemada 2=Descosida 3=Cortada* *4=Agujero o rasgón mayor a 5 cm 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
106. ¿Ha reparado la cortina? *0=No 1=Sí*						Si "No" pase a 95
107. ¿Qué reparación realizó? *1=Coser 2=Poner parche 3=Pegamento 99=Otra*						
Si es "Otro" Especifique ¿Cuál?						
108. ¿Cómo observa la cortina? *1= Extendida 2=Nudo 3=Amarrada 4=Corrida a un lado 9=Otro*						
Si es "Otro" Especifique ¿Cuál?						
109. ¿Cómo permanece la cortina cuando llueve? *1= Nudo 2=Amarrada 3=Corrida a un lado 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
110. ¿En algún momento del día la cortina impregnada está expuesta directamente a los rayos del sol? *0=No 1=Sí*						
111. ¿La cortina está cubierta de polvo? *0=No 1=Sí*						

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Aspecto a observar de las cortinas	CORTINA 1	CORTINA 2	CORTINA 3	CORTINA 4	CORTINA 5	
112. ¿Alguna vez ha lavado la(s) cortina? *0=No 1=Sí*						Si "No" pase a 104
113. ¿Cuántas veces la ha lavado?						
114. ¿Con qué la(s) lavó? *1=Solo agua 2=Jabón de barra 3=Cloro líquido* *4=Detergente en polvo 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
115. ¿Cuál fue la marca del jabón o detergente utilizado para lavarla(s)?						
116. ¿Cómo secó la cortina? *1=Directamente bajo el sol 2=Parcialmente bajo el sol* *3=Bajo la sombra 99=Otro*						
Si es "Otro" Especifique ¿Cuál?						
117. ¿Qué tan limpia está la cortina? *1=Limpia 2=Medio limpia 3=Sucia 4=Muy sucia*						

118. ¿Está satisfecho con la manera en que se le entregaron las cortinas del proyecto?	☐ 0 = NO ☐ 1 = SI ☐ 2 = No sabe / No responde
119. ¿Cómo considera la calidad del material de las cortinas?	☐ 1 = Mala ☐ 2 = Regular ☐ 3 = Buena
120. En una escala de 1 a 5, donde 1 es nada y 5 es mucho. ¿Qué tanto le ha gustado utilizar las cortinas?	
121. Si las cortinas fueran vendidas en el mercado, ¿usted estaría dispuesto(a) a comprarlas?	☐ 0 = NO ¿Por qué? ☐ 1 = SI ☐ 2 = No sabe / No responde
122. ¿Recomendaría la utilización de las cortinas con insecticida de larga duración?	☐ 0 = NO ¿Por qué? ☐ 1 = SI ☐ 2 = No sabe / No responde
123. ¿Ha observado alguna diferencia en la presencia de zancudos con la instalación de las cortinas día proyecto?	☐ 0 = NO ☐ 1 = SI ☐ 2 = No sabe / No responde

124. ¿Ha observado si ha disminuido el número de otros insectos o animales desde la instalación?	☐ 0 = NO ☐ 1 = SI → ☐ 2 = No sabe / No responde	¿Cuáles?	☐ 1=Arañas ☐ 2=Cucarachas ☐ 3=Grillos ☐ 4=Moscas ☐ 5=Alacranes ☐ 6=Cucarrones ☐ 7=Salamanquejas ☐ 99=Otros ¿Cuáles? ___________________

Hora de Finalización: ______: ______ ☐ AM ☐ PM

Nombre de Encuestador: ____________________________________ Firma de Coordinadora: ________________________

VIII. Casos de Dengue, Chikungunya y zika (Hoja Anexa)		**Fecha de Visita:**	DD / MM / AAAA	**Código de la vivienda**									

Miembro del hogar No	79. Nombres y Apellidos	80. Parentesco con el jefe del Hogar 1 = Jefe del hogar 2 = Padre 3 = Madre 4 = Cónyuge / Compañer@ 5 = Hij@ 6 = Hij@ no biológico 7 = Ti@ 8 = Abuel@ 9 = Otro familiar 10 = No pariente	81. ¿Cuantos años cumplidos tiene? (infante=0)	¿Cuántas veces ha padecido la enfermedad? ¿Ha sido diagnosticada por un médico?						85. ¿Cuándo fue la última vez que estuvieron enfermos por dengue, chikungunya o zika? 1= Últimos 15 dias 2= Hace un mes 3= Hace más de 1 mes 4= No sabe			86. En esa última vez. ¿Dónde consultó inicialmente cuando comenzó la enfermedad? 1= Drogueria o farmacia 2= Vecina/o 3 = Familiar 4 = Centro de Salud 5= Hospital 6= Médico particular 7= Curandero o chaman 8 = No consultó
				82. DEN		83. CHI		84. ZIK					
				No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	DEN	CHI	ZIK	
1					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
2					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
3					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
4					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
5					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
6					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
7					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
8					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
9					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				

IX. EVENTOS ADVERSOS (Hoja Anexa)

Membro del Hogar No	88. Nombre y Apellido del miembro del hogar que presentó el evento	89. Parentesco con el jefe del Hogar 1 = Jefe del hogar 2 = Padre 3 = Madre 4 = Cónyuge / Compañer@ 5 = Hij@ 6 = Hij@ no biológico 7 = Ti@ 8 = Abuel@ 9 = Otro familiar 10 = No pariente	90. Edad	91. Fecha en que inicio el evento	92. Describa el tipo de reacción que presentó	93. En esa última vez. ¿Dónde consultó inicialmente cuando comenzó la enfermedad?		94. ¿Recibió diagnóstico médico? *0 = No 1 = Si ¿Cuál?* 3 = No sabe / No se acuerda	95. ¿Recibió tratamiento médico? *0 = No 1 = Si ¿Cuál?* 3 = No sabe / No se acuerda
						Lugar 0=No acudió 1=Clinica Dumian 2=Clínica San Sebastián 3=Clínica de Especialistas 99=Otro ¿Cuál?	Fecha en que acudió al servicio de salud		
1				DD/MM/AA			DD/MM/AA		
2				DD/MM/AA			DD/MM/AA		
3				DD/MM/AA			DD/MM/AA		
4				DD/MM/AA			DD/MM/AA		

XI. Miembros de nuevo hogar en vivienda con intervención		**Fecha de Visita:**	DD / MM / AAAA	**Código de la vivienda**									

Miembro del Hogar No	125. Nombres y Apellidos	126. Parentesco con el jefe del Hogar **1 = Jefe del hogar** 2 = Padre 3 = Madre 4 = Cónyuge / Compañer@ 5 = Hij@ 6 = Hij@ no biológico 7 = Ti@ 8 = Abuel@ 9 = Otro familiar 10 = No pariente	127. ¿Cuantos años cumplidos tiene? (infante=0)	128. Sexo 1=M 2=F	129. ¿En qué ocupó la mayor parte del tiempo la semana pasada? 1 = Trabajando 2 = No trabajó, pero tiene trabajo 3 = Buscando trabajo 4 = Estudiando 5 = Oficios del hogar 6 = Pensionado 7 = Rentista 8 = Incapacitado permanente 9 = Otro: ______________ 10= NS / NR	130. ¿Sitio en el que pasa la mayor parte del tiempo? 1 = Trabajo en la ciudad 2 = Trabajo fuera de la ciudad 3 = Casa 4 = Estudio 5 = Negocio 6 = Espacio público 7 = Otro: _________ 8= NS / NR	131. Ubicación ¿Dónde? Por favor díganos la dirección o describa la ubicación de la forma más exacta posible.
1		1					
2							
3							
4							
5							
6							
7							
8							
9							

Miembro de la familia No	132. Nivel de Escolaridad 1 – No sabe leer y escribir 2 – Básica primaria incompleta 3 - Básica primaria completa 4 – Bachillerato incompleto 5 – Bachillerato Completo 6 – Técnico - Tecnólogo 7 – Universitario 8 – Posgrado 9 – NS/NR	133. ¿Cuál es su afiliación al sistema de salud? 1 – NO 2 – Régimen Contributivo 3 – Régimen subsidiado 4 – Régimen especial 5 – Vinculado 6 – NS/NR	134. ¿Cuál es el nombre de su EPS?	¿Algún miembro de su familia ha tenido dengue, chikungunya o zika? ¿Quiénes? ¿Cuántas veces ha padecido la enfermedad? ¿Ha sido diagnosticada por un médico?						138. ¿Cuándo fue la última vez que estuvieron enfermos por dengue, chikungunya o zika? 1= Últimos 15 días 2= Hace un mes 3= Hace más de 1 mes 4= No sabe			139. En esa última vez. ¿Dónde consultó inicialmente cuando comenzó la enfermedad? 1= Droguería o farmacia 2= Vecina/o 3 = Familiar 4 = Centro de Salud 5= Hospital 6= Médico particular 7= Curandero o chaman 8 = No consultó
				135. DEN		136. CHI		137. ZIK					
				No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	No Veces	Diagnóstico médico	DEN	CHI	ZIK	
1					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
2					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
3					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
4					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
5					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
6					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
7					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
8					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				
9					☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO		☐1 = SI ☐2 = NO				

Appendix D2. Cross-sectional household survey

FUNDACIÓN SANTA FE DE BOGOTÁ
Eje de Salud Pública

Versión: 06
Fecha: Diciembre 1 de 2015
Revisores: JQ ,SC, HR, DG

ENCUESTA ENTOMOLÓGICA - VIVIENDAS

Dia ____ Mes ____ Año ____ ☐ Visita Inicial ☐ Visita de Instalación ☐ Seguimiento 1 ☐ Seguimiento 2

Dirección ______________________

Código de la vivienda ☐☐☐☐☐☐☐

Barrio ______________________

Presente ☐ **Ausente** ☐ **Renuente** ☐

Nombre del encuestador: ______________________

Número de personas en la vivienda ☐

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos dias lo desocupó o lavó?	Ubicación: 1=Dentro 0=Fuera	Accesible: 1=Si, 0=No	Techo: 1=Total 2=Parcial 3=No	Capacidad: 1 = ≤ 20 L 2 = >20L	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	Nivel Agua: 1 = Menos que bajo, 2 = Bajo, 3 = Medio, 4 = Alto	Tipo de agua: 1 = Llave 2 = Luvia 3 = Ambas	Tapado: 1 = Total 2 = Parcial 3 = No	Uso: 0= No se utiliza 1 = Aseo 2 = Consumo 3 = Bebedero 4 = Reserva 5 = Sanitario 6 = Otros	Sedimento: 0=No 1=Hojas 2=Musgo 3=Tierra 4=Semillas 5=Residuos animales 6=Palos 7=Frutas 8=Arena 99=Otro	Intervención: 0 =Ninguno 1 = Abate (Tiempo) 2 = Cloro granulado / Pastilla 3 = Vectobac 4 = Biológico 99 = Otro	Larvas: 0 = 0, 1 = 1-9, 2 = 10-50, 3 = >51	Cantidad de pupas
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

RECUERDE REGISTRAR SOLO RECIPIENTES CON AGUA

Tipos de recipiente: 1=Tanque bajo, 2=Tanque alto, 3=Alberca tipo 1 (Fregadero sobre agua almacenada), 4=Alberca tipo 2, 5=Tarro, vasija, platón, 6=Balde, caneca pequeña, 7=Florero, 8=Llantas, 9=Sumidero de agua, 10=Latas, botellas, inservibles, 11=Naturales, 12=Canaletas, 99=Otros

FUNDACIÓN SANTA FE DE BOGOTÁ
Eje de Salud Pública

Versión: 06
Fecha: Diciembre 1 de 2015
Revisores: JQ ,SC, HR, DG

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos dias lo desocupó o lavó?	**Ubicación:** *1=Dentro* *0=Fuera*	**Accesible:** *1=Si,* *0=No*	**Techo:** *1=Total* *2=Parcial* *3=No*	**Capacidad:** *1 = ≤ 20 L* *2 = >20L*	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	**Nivel Agua:** *1 = Menos que bajo,* *2 = Bajo,* *3 = Medio,* *4 = Alto*	**Tipo de agua:** *1 = Llave* *2 = Luvia* *3 = Ambas*	**Tapado:** *1 = Total* *2 = Parcial* *3 = No*	**Uso:** *0= No se utiliza* *1 = Aseo* *2 = Consumo* *3 = Bebedero* *4 = Reserva* *5 = Sanitario* 6 = Otros	**Sedimento:** *0=No 1=Hojas* *2=Musgo* *3=Tierra* *4=Semillas* *5=Residuos animales* *6=Palos* *7=Frutas* *8=Arena* *99=Otro*	**Intervención:** *0 =Ninguno* *1 = Abate (Tiempo)* *2 = Cloro granulado / Pastilla* *3 = Vectobac* *4 = Biológico* *99 = Otro*	**Larvas:** *0 = 0,* *1 = 1-9,* *2 = 10-50,* *3 = >51*	Cantidad de pupas
10																		
11																		
12																		
13																		
14																		

Número de adultos capturados ____

Observaciones: ______________________

Nombre y apellidos de quién atiende la visita: ______________________

Firma Supervisora: ______________________

En cuánto ubica el ingreso mensual de su familia? ____

(NO LEA OPCIONES, ESPERE LA RESPUESTA)

1 = <1 SMLV (0 a menos de $644.350); 2 = Entre 1 y 2 SMLV (644.350 - 1.288.700); 3 = Entre 2 y 3 SMLV (1.288.700 - 1.933.050); 4 = Entre 3 y 4 SMLV (1.933.050 - 2.577.400); 5 = Entre 4 y 5 SMLV (2.577.400 - 3.221.750); 6 = Más de 3.221.750; 7 = No sabe

¿Cuánto dinero gasta al mes para reducir la incomodidad ocasionada por los mosquitos? ____

¿En qué? ______________________

Appendix D3. Cross-public space survey

FUNDACIÓN SANTA FE DE BOGOTÁ
Eje de Salud Pública

Versión: 06
Fecha: Octubre 13 de 2015
Revisores: HR

ENCUESTA ENTOMOLÓGICA - ESPACIO PÚBLICO

Dia		**Mes**		**Año**		**Código**					9			**Nombre del encuestador:**	

Dirección ________ **Barrio** ________ **Tipo de espacio público** ________

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos dias lo desocupó o lavó?	Ubicación 1=Dentro 0=Fuera	Accesible 1=Si, 0=No	Techo: 1=Total 2=Parcial 3=No	Capacidad 1 = ≤ 20 L 2 = >20L	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	Nivel Agua: 1 = Menos que bajo, 2 = Bajo, 3 = Medio, 4 = Alto	Tipo de agua: 1 = Llave 2 = Luvia 3 = Ambas	Tapado: 1 = Total 2 = Parcial 3 = No	Uso: 0= No se utiliza 1 = Aseo 2 = Consumo 3 = Bebedero 4 = Reserva 5 = Sanitario 6 = NA 7 = Otros	Sedimento: 0=No 1=Hojas 2=Musgo 3=Tierra 4=Semillas 5=Residuos animales 6=Palos 7=Frutas 8=Arena 99=Otro	Intervención 0 =Ninguno 1 = Abate (Tiempo) 2 = Cloro granulado / Pastilla 3 = Vectobac 4 = Biológico 5 = NA 99 = Otro	Larvas: 0 = 0, 1 = 1-9, 2 = 10-50, 3 = >51	Cantidad de pupas
1																		
2																		
3																		
4																		

Dia		**Mes**		**Año**		**Código**					9			**Nombre del encuestador:**	

Dirección ________ **Barrio** ________ **Tipo de espacio público** ________

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos dias lo desocupó o lavó?	Ubicación 1=Dentro 0=Fuera	Accesible 1=Si, 0=No	Techo: 1=Total 2=Parcial 3=No	Capacidad 1 = ≤ 20 L 2 = >20L	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	Nivel Agua: 1 = Menos que bajo, 2 = Bajo, 3 = Medio, 4 = Alto	Tipo de agua: 1 = Llave 2 = Luvia 3 = Ambas	Tapado: 1 = Total 2 = Parcial 3 = No	Uso: 0= No se utiliza 1 = Aseo 2 = Consumo 3 = Bebedero 4 = Reserva 5 = Sanitario 6 = NA 7 = Otros	Sedimento: 0=No 1=Hojas 2=Musgo 3=Tierra 4=Semillas 5=Residuos animales 6=Palos 7=Frutas 8=Arena 99=Otro	Intervención 0 =Ninguno 1 = Abate (Tiempo) 2 = Cloro granulado / Pastilla 3 = Vectobac 4 = Biológico 5 = NA 99 = Otro	Larvas: 0 = 0, 1 = 1-9, 2 = 10-50, 3 = >51	Cantidad de pupas
1																		
2																		
3																		
4																		

Tipos de recipiente: 1=Tanque bajo, 2=Tanque alto, 3=Alberca tipo 1 (Fregadero sobre agua almacenada), 4=Alberca tipo 2,
5=Tarro, vasija, platón, 6=Balde, caneca pequeña, 7=Florero, 8=Llantas, 9=Sumidero de agua, 10=Latas, botellas, inservibles, 11=Naturales, 12=Canaletas, 99=Otros

FUNDACIÓN SANTA FE DE BOGOTÁ
Eje de Salud Pública
ENCUESTA ENTOMOLÓGICA - ESPACIO PÚBLICO

Versión: 06
Fecha: Octubre 13 de 2015
Revisores: HR

Dia		Mes		Año		Código					9			Nombre del encuestador:	

Dirección ______________________ **Barrio** ______________________ **Tipo de espacio público** ______________________

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos días lo desocupó o lavó?	Ubicación 1=Dentro 0=Fuera	Accesible 1=Si, 0=No	Techo: 1=Total 2=Parcial 3=No	Capacidad 1 = ≤ 20 L 2 = >20L	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	Nivel Agua: 1 = Menos que bajo, 2 = Bajo, 3 = Medio, 4 = Alto	Tipo de agua: 1 = Llave 2 = Luvia 3 = Ambas	Tapado: 1 = Total 2 = Parcial 3 = No	Uso: 0= No se utiliza 1 = Aseo 2 = Consumo 3 = Bebedero 4 = Reserva 5 = Sanitario 6 = NA 7 = Otros	Sedimento: 0=No 1=Hojas 2=Musgo 3=Tierra 4=Semillas 5=Residuos animales 6=Palos 7=Frutas 8=Arena 99=Otro	Intervención 0 =Ninguno 1 = Abate (Tiempo) 2 = Cloro granulado / Pastilla 3 = Vectobac 4 = Biológico 5 = NA 99 = Otro	Larvas: 0 = 0, 1 = 1-9, 2 = 10-50, 3 = >51	Cantidad de pupas
1																		
2																		
3																		
4																		

Dia		Mes		Año		Código					9			Nombre del encuestador:	

Dirección ______________________ **Barrio** ______________________ **Tipo de espacio público** ______________________

Nº de registro	Tipo de Recipiente	Cantidad	¿Hace cuantos días lo desocupó o lavó?	Ubicación 1=Dentro 0=Fuera	Accesible 1=Si, 0=No	Techo: 1=Total 2=Parcial 3=No	Capacidad 1 = ≤ 20 L 2 = >20L	Medidas Largo (cm)	Medidas Ancho o diámetro (cm)	Medidas Alto (cm)	Nivel Agua: 1 = Menos que bajo, 2 = Bajo, 3 = Medio, 4 = Alto	Tipo de agua: 1 = Llave 2 = Luvia 3 = Ambas	Tapado: 1 = Total 2 = Parcial 3 = No	Uso: 0= No se utiliza 1 = Aseo 2 = Consumo 3 = Bebedero 4 = Reserva 5 = Sanitario 6 = NA 7 = Otros	Sedimento: 0=No 1=Hojas 2=Musgo 3=Tierra 4=Semillas 5=Residuos animales 6=Palos 7=Frutas 8=Arena 99=Otro	Intervención 0 =Ninguno 1 = Abate (Tiempo) 2 = Cloro granulado / Pastilla 3 = Vectobac 4 = Biológico 5 = NA 99 = Otro	Larvas: 0 = 0, 1 = 1-9, 2 = 10-50, 3 = >51	Cantidad de pupas
1																		
2																		
3																		
4																		

Tipos de recipiente: 1=Tanque bajo, 2=Tanque alto, 3=Alberca tipo 1 (Fregadero sobre agua almacenada), 4=Alberca tipo 2, 5=Tarro, vasija, platón, 6=Balde, caneca pequeña, 7=Florero, 8=Llantas, 9=Sumidero de agua, 10=Latas, botellas, inservibles, 11=Naturales, 12=Canaletas, 99=Otros

Appendix D4. Supplementary information: Household Indexes per season

Table D4-1. Baseline household entomological indexes comparison between intervention and control groups of Sector 1 stratified per season

Season		Dry			Rainy		
Area		**I**	**C**	**Total**	**I**	**C**	**Total**
Households		38	465	841	305	196	500
Persons		1514	1828	3342	1187	697	1884
Number of Containers		863	1234	2097	695	464	1159
Larvae and or pupae	Positive containers	97	148	245	102	81	183
	Positive households	86	191	277	90	59	149
Pupae	Positive containers	27	47	74	24	25	49
	Positive households	26	42	68	23	24	47
Number of Pupae		518	820	1338	312	390	702
Larvae + pupae	HI %	22	41	33	30	30	30
indices	CI %	11	12	12	15	17	16
	BI	26	32	29	34	41	37
Pupae indices	HI %	7	9	8	8	12	9
	CI %	3	4	4	3	5	4
	BI	7	10	9	8	13	10
	PPI	0.34	0.45	0.40	0.26	0.56	0.37

Table D4-2. Baseline household entomological indexes comparison between intervention and control groups of Sector 2 stratified per season

Season		Dry			Rainy		
Area		**I**	**C**	**Total**	**I**	**C**	**Total**
Households		423	0	423	608	289	897
Persons		1527	0	1527	2112	1030	3142
Number of Containers		759	0	759	1060	564	1624
Larvae and or pupae	Positive containers	89	0	89	111	71	182
	Positive households	72	0	72	94	19	113
Pupae	Positive containers	19	0	19	16	20	36
	Positive households	16	0	16	15	64	79
Number of Pupae		691	0	691	395	454	849
Larvae + pupae indices	HI %	17	0	17	15	7	12
	CI %	12	0	12	10	13	11
	BI	21	0	21	18	25	20
Pupae indices	HI %	4	0	4	2	22	9
	CI %	3	0	3	2	4	2
	BI	4	0	4	3	11	4
	PPI	0.45	0	0.45	0.19	0.44	0.27

Table D4-3. Endline household entomological indexes comparison between intervention and control groups of Sector 1 stratified per season

Season		Dry			Rainy		
Area		**I**	**C**	**Total**	**I**	**C**	**Total**
Households		261	282	543	289	50	339
Persons		955	1103	2058	1110	186	1296
Number of Containers		676	757	1433	779	133	912
Larvae and or pupae	Positive containers	66	85	151	41	7	48
	Positive households	56	73	129	39	7	46
Pupae	Positive containers	31	32	63	8	3	11
	Positive households	24	31	55	8	3	11
Number of Pupae		783	855	1638	77	80	157
Larvae + pupae indices	HI %	21	26	24	13	14	14
	CI %	12	14	13	6	7	6
	BI	25	30	28	14	14	14
Pupae indices	HI %	9	11	10	13	14	14
	CI %	6	5	5	6	7	6
	BI	12	11	12	14	14	14
	PPI	0.82	0.78	0.80	0.07	0.43	0.25

Table D4-4. Endline household entomological indexes comparison between intervention and control groups of Sector 2 stratified per season

Season		Dry			Rainy		
Area		**I**	**C**	**Total**	**I**	**C**	**Total**
Households		272	31	303	260	52	312
Persons		1077	143	1220	921	221	1142
Number of Containers		452	57	509	550	90	640
Larvae and or pupae	Positive containers	27	12	39	25	10	35
	Positive households	26	11	37	25	10	35
Pupae	Positive containers	7	2	9	9	2	11
	Positive households	7	2	9	9	2	11
Number of Pupae		61	38	99	162	15	177
Larvae + pupae indices	HI %	10	35	23	10	19	14
	CI %	6	21	14	5	11	8
	BI	10	39	24	10	19	14
Pupae indices	HI %	3	6	5	10	19	14
	CI %	2	4	3	5	11	8
	BI	3	6	5	10	19	14
	PPI	0.06	0.27	0.16	0.18	0.07	0.12

Appendix D5. Supplementary information: Public spaces Indexes per season

Table D5-1. Baseline public space entomological indexes comparison between intervention and control groups of Sector 1 stratified per season

Season	**Dry**					**Rainy**				
Area	**Intervention**		**Control**		**Total**	**Intervention**		**Control**		**Total**
	n	**%**	**n**	**%**		**n**	**%**	**n**	**%**	
Inspected public spaces	180	42.86	240	57.14	420	182	58.52	129	41.48	311
Total of containers	154	42.90	205	57.10	359	198	64.08	111	35.92	309
Positive containers for larvae +pupae	37	40.66	54	59.34	91	59	60.20	39	39.80	98
Positive containers for pupae	33	40.24	49	59.76	82	50	61.73	31	38.27	81
Positive public space for larvae + pupae	13	30.23	30	69.77	43	31	68.89	14	31.11	45
Positive public space for pupae	13	30.95	29	69.05	42	30	69.77	13	30.23	43
Estimated pupas	57	20.21	225	79.79	282	268	71.66	106	28.34	374
Public space larvae + pupae index	7%		13%			17%		11%		
Public pupa index	7%		12%			16%		10%		
Container larva + pupae index	24%		26%			30%		35%		
Container pupae index	21%		24%			25%		28%		
Breteau larvae + pupae Index	20.56		22.50			32.42		30.23		
Breteau pupae index	21.43		23.90			25.25		27.93		

Table D5-2. Baseline public entomological indexes comparison between intervention and control groups of Sector 2 stratified per season

Season	Dry					Rainy				
Area	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	96	42.11	132	57.89	228	461	80.74	110	19.26	571
Total of containers	172	25.75	86	12.87	668	466	80.76	111	19.24	577
Positive containers for larvae +pupae	22	11.64	7	3.70	189	148	91.93	13	8.07	161
Positive containers for pupae	11	12.22	7	7.78	90	98	89.09	12	10.91	110
Positive public space for larvae + pupae	14	8.70	1	0.62	161	52	88.14	7	11.86	59
Positive public space for pupae	8	9.41	1	1.18	85	39	82.98	8	17.02	47
Estimated pupas	75	11.43	3	0.46	656	382	79.09	101	20.91	483
Public space larvae + pupae index	15%		1%			11%		6%		
Public pupa index	8%		1%			8%		7%		
Container larvae + pupae index	13%		8%			32%		12%		
Container pupae index	6%		8%			21%		11%		
Breteau larvae + pupae index	22.92		5.30			32.10		11.82		
Breteau pupae index	6.40		8.14			21.03		10.81		

Table D5-3. Endline public entomological indexes comparison between intervention and control groups of Sector 1 stratified per season

Season	Dry					Rainy				
Area	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	0	0	0	0	0	327	50	326	50	653
Total of containers	0	0	0	0	0	327	54	280	46	607
Positive containers for larvae +pupae	0	0	0	0	0	81	45	98	55	179
Positive containers for pupae	0	0	0	0	0	25	47	28	53	53
Positive Public space for larvae + pupae	0	0	0	0	0	67	47	75	53	142
Positive Public space for pupae	0	0	0	0	0	24	49	25	51	49
Estimated pupas	0	0	0	0	0	232	39	361	61	593
Public space larvae + pupae index	0		0			20%		23%		
Public pupa index	0		0			7%		8%		
Container larvae + pupae index	0		0			25%		35%		
Container pupae index	0		0			8%		10%		
Breteau larvae + pupae index	0		0			24.77		30.06		
Breteau pupae index	0		0			7.65		10.00		

Table D5-4. Endline public entomological indexes comparison between intervention and control groups of Sector 2 stratified per season

Season	Dry					Rainy				
Area	Intervention		Control		Total	Intervention		Control		Total
	n	%	n	%		n	%	n	%	
Inspected public spaces	493	81	113	19	606	141	55	117	45	258
Containers accessible for inspection	552	66	118	14	836	176	59	122	41	298
Positive containers for larvae +pupae	109	58	9	5	189	19	59	13	41	32
Positive containers for pupae	32	36	1	1	90	8	73	3	27	11
Positive public space for larvae + pupae	75	47	9	6	161	16	55	13	45	29
Positive public space for pupae	29	34	1	1	85	8	67	4	33	12
Estimated pupas	472	72	4	1	656	51	91	5	9	56
Public space larvae + pupae index	15%		8%			11%		11%		
Public pupa index	6%		1%			6%		3%		
Container larvae + pupae index	20%		8%			11%		11%		
Container pupae index	6%		1%			5%		2%		
Breteau larvae + pupae index	22.11		7.96			13.48		11.11		
Breteau pupae index	5.80		0.85			4.55		2.46		

Appendix D6. Supplementary information: Household type of containers and pupal productivity

Table D6-1. Baseline frequency of water holding containers and pupal productivity in households of sector 1, stratified by intervention and control areas.

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I *		C *		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	92	5.90	156	9.20	83	10.10	125	10.40	5	9.80	5	6.90	5.43	3.21
Elevated tank (plastic)	7	0.30	1	0.10	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	561	36.10	493	29.00	683	82.90	945	78.10	38	74.50	52	72.20	6.77	10.55
Water tank type 2 **	96	6.20	84	4.90	54	6.60	98	8.10	4	7.80	3	4.20	4.17	3.57
Jar, vessels	206	13.30	265	15.60	4	0.50	8	0.70	1	2.00	2	2.80	0.49	0.75
Buckets	402	25.80	443	26.10	0	0	21	1.70	0	0	6	8.30	0.00	1.35
Flower vases pots	70	4.50	61	3.60	6	1.00	2	0.20	3	5.90	1	1.40	4.29	1.64
Used tires	3	0.20	3	0.20	0	0	0	0	0	0	0	0	0	0
Rainwater drain	1	0.10	0	0	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	87	5.60	160	9.40	0	0	6	0.50	0	0	2	2.80	0	1.25
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	33	2.10	32	1.90	0	0	4	0.30	0	0	1	1.40	0	3.13
Total	1558	100	1698	100	830	100	1209	100	51	100	72	100	3.27	4.24

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Table D6-2 Baseline frequency of water holding containers and pupal productivity in households of sector 2 stratified by intervention and control areas.

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I*		C *		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	64	3.52	18	3.17	0	0	0	0.00	0	0	0	0	0	0
Elevated tank (plastic)	4	0.22	2	0.35	0	0	0	0.00	0	0	0	0	0	0
**Water tank type 1 ** **	930	51.13	215	37.85	1001	92.26	346	76.21	25	71.43	15	62.50	2.69	6.98
**Water tank type 2 ** **	123	6.76	35	6.16	73	6.73	74	16.30	5	14.29	3	12.50	4.07	8.57
Jar, vessels	483	26.55	136	23.94	1	0.09	30	6.61	1	2.86	1	4.17	0.21	0.74
Buckets	150	8.25	109	19.33	9	0.83	4	0.88	3	8.57	5	20.83	2	4.59
Flower vases pots	31	1.70	22	3.87	1	0.09	0	0	1	2.86	0	0	3.23	0
Used tires	4	0.22	4	0.70	0	0	0	0	0	0	0	0	0	0
Rainwater drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	24	1.32	11	1.94	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	6	0.33	12	2.11	0	0	0	0	0	0	0	0	0	0
Total	1819	100	564	100	1085	100	454	100	35	100	24	100	1.92	4.26

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Table D6-3. Endline frequency of water holding containers and pupal productivity in sector 1 in households stratified by intervention and control areas.

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae				Container Index	
	I*		C*		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	46	3.90	43	5.90	131	15.23	49	5.24	4	10.26	3	8.57	8.70	6.98
Elevated tank (plastic)	2	0.17	1	0.14	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	488	41.43	258	35.39	589	68.49	819	87.50	25	64.10	30	85.71	5.12	11.63
Water tank type 2 **	78	6.62	43	5.90	133	15.47	68	7.26	6	15.38	2	5.71	7.69	4.65
Jar, vessels	282	23.94	185	25.38	2	0.23	0	0	2	5.13	0	0	0.71	0
Buckets	228	19.35	164	22.50	4	0.47	0	0	1	2.56	0	0	0.44	0
Flower vases pots	25	2.12	13	1.78	0	0	0	0	0	0	0	0	0	0
Used tires	2	0.17	3	0.41	1	0.12	0	0	1	2.56	0	0	50.00	0
Rainwater drain	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	9	0.76	10	1.37	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	18	1.53	9	1.23	0	0	0	0	0	0	0	0	0	0
Total	1178	100	729	100	860	100	936	100	39	100	35	100	3.31	4.80

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Table D6-4. Endline frequency of water holding containers and pupal productivity in sector 2 in households stratified by intervention and control areas

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I*		C*		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	32	3.65	0	0	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	1	0.11	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	474	54.11	229	82.67	177	79.37	52	79.19	15	75.00	3	75.00	2.75	6.31
Water tank type 2 **	62	7.08	42	15.16	41	18.39	0	0	2	10.00	0	0	2.90	0
Jar, vessels	277	31.62	1	0.36	0	0.00	1	1.52	1	5.00	1	25.00	0.31	3.55
Buckets	105	11.99	5	1.81	5	2.24	0	0	2	10.00	0	0	1.67	0
Flower vases pots	8	0.91	0	0	0	0	0	0	0	0	0	0	0	0
Used tires	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rainwater drain	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cans, bottles, unusable (trash)	37	4.22	0	0	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	6	0.68	0	0	0	0	0	0	0	0	0	0	0	0
Total	1002	114.4	277	100	223	100	53	100	20	100	4	100	1.74	4.00

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Appendix D7. Supplementary information: Public spaces type of containers and pupal productivity

Table D7-1. Baseline frequency of water holding containers and pupal productivity in public spaces of sector 1 stratified by intervention and control areas

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I*		C*		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	5	1.42	3	0.95	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	1	0.28	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 2 **	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jar, vessels	19	5.40	12	3.80	0	0	0	0	0	0	0	0	0	0
Buckets	15	4.26	5	1.58	0	0	0	0	0	0	0	0	0	0
Flower vases pots	1	0.28	0	0.00	0	0	0	0	0	0	0	0	0	0
Used tires	8	2.27	4	1.27	0	0	0	0	0	0	0	0	0	0
Rainwater drain	230	65.34	226	71.52	325	100	308	93.05	44	100	45	97.83	19	20
Cans, bottles, unusable (trash)	64	18.18	60	18.99	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	9	2.56	6	1.90	0	0	23	6.94	0	0	1	2.17	0	17
Total	352	100	316	100	325	100	331	100	44	100	46	100	13	15

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Table. D7-2. Baseline frequency of water holding containers and pupal productivity in public spaces of sector 2, stratified by intervention and control areas

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I*		C*		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	0	0	2	1.02	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
**Water tank type 1 ** **	0	0	0	0	0	0	0	0	0	0	0	0	0	0
**Water tank type 2 ** **	0	0	0	0	0	6.54	0	0	0	0	0	0	0	0
Jar, vessels	15	2.35	14	7.11	30	0.22	0	0	2	2.90	0	0	13	0
Buckets	17	2.66	0	0	1	0.22	0	0	1	1.45	0	0	6	0
Flower vases pots	0	0	0	0	1	8.71	0	0	1	1.45	0	0	0	0
Used tires	18	2.82	0	0	40	84.31	0	0	1	1.45	0	0	6	0
Rainwater drain	547	85.74	176	89.34	387	0	104	100	64	92.75	8	100	12	5
Cans, bottles, unusable (trash)	39	6.11	5	2.54	0	0	0	0	0	0	0	0	0	0
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	2	0.31	0	0	0	100	0	0	0	0	0	0	0	0
Total (n)	638	100	197	100	459	0	104	100	69	100	8	100	11	4

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side.

Table D7-3. End line frequency of water holding containers and pupal productivity in public spaces of sector 1, stratified by intervention and control areas

Types of containers	Containers n(%)				Pupal productivity				Containers with pupae n(%)				Container Index	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	0	0	2	0.71	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	2	0.61	0	0.00	21	9.05	0	0	1	4	0	0	50	0
Water tank type 2 **	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jar, vessels	9	2.75	6	2.14	0	0	0	0	0	0	0	0	0	0
Buckets	4	1.22	2	1	0	0	3	0.83	0	0	1	3.57	0	5
Flower vases pots	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used tires	8	2.45	8	2.86	0	0	0	0	0	0	0	0	0	0
Rainwater drain	246	75.23	222	79.29	210	90.52	324	89.75	23	92.00	26	92.86	9	12
Cans, bottles, unusable (trash)	57	17.43	40	14.29	1	0.43	34	9.42	1	4	1	3.57	2	3
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	1	0.31	0	0	0	0	0	0	0	0	0	0	0	0
Total (n)	327	100.00	280	100	232	100	361	100	25	100	28	100	8	10

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side

Table D7-4. End line frequency of water holding containers and pupal productivity in public spaces of sector 2, stratified by intervention and control areas

Types of containers	Containers n (%)				Pupal productivity				Containers with pupae n (%)				Container Index	
	I		C		I		C		I		C		I	C
	n	%	n	%	n	%	n	%	n	%	n	%	%	%
Ground (plastic)	0	0	1	0.42	0	0	0	0	0	0	0	0	0	0
Elevated tank (plastic)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 1 **	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water tank type 2 **	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jar, vessels	12	1.65	6	2.50	0	0	0	0	0	0	0	0	0	0
Buckets	4	0.55	1	0.42	18	3.44	0	0	1	2.5	0	0	25	0
Flower vases pots	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used tires	35	4.81	2	0.83	10	1.91	0	0	1	2.5	0	0	3	0
Rainwater drain	550	75.55	169	70.42	495	94.65	4	44.44	38	95	2	50	7	1
Cans, bottles, unusable (trash)	127	17.45	61	25.42	0	0	5	55.56	0	0	2	50	0	3
Natural	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (n)	728	100	240	100	523	100	9	100	40	100	4	100	5	2

*I: intervention, C: control, **Wash basin: artificial storage water tanks used mainly for laundry and household cleaning, type 1 has the sink over the basin and type has it on one side

Appendix D8. Supplementary information: Differences in differences (DID) and Differences of endline (DOE) per Breteau and pupae per person index

Table D8-1. Overall Household differences in differences (DID) and differences of endline (DOE) per Breteau and pupae per person index

Index	Group	n	Baseline	Endline	Diff	Ratio	DID	DOE	Ratio of Ratios
	I	2884	23	12	-11	0.52	-6	-15	0.62
BI	C	1365	32	27	-5	0.84			
	I	2884	0.3	0.25	-0.05	0.83	0.18	-0.35	0.65
PPI	C	1365	0.47	0.6	0.13	1.28			

Table D8-2. Household differences in differences (DID) and differences of endline (DOE) per Breteau and pupae per person index per sectors

Sector	Index	Group	n	Baseline	Endline	Diff	Ratio	DID	DOE	Ratio of Ratios
		I	1239	28	19	-9	0.68	-2	-9	0.85
	BI	C	993	35	28	-7	0.80			
1		I	1239	0.31	0.42	0.11	1.35	-0.14	-0.31	0.89
	PPI	C	993	0.48	0.73	0.25	1.52			
		I	1645	19.3	10	-9.3	0.52	-7.7	-15	0.55
	BI	C	372	26.6	25	-1.6	0.94			
2		I	1562	0.3	0.1	-0.2	0.33	0.04	-0.1	0.73
	PPI	C	372	0.44	0.2	-0.24	0.45			

Appendix D9. Supplementary information: Differences in differences (DID) and Differences of endline (DOE) per Breteau in public spaces

Table D9-1. Overall public spaces differences in differences (DID) and differences of endline (DOE) per Breteau index

Index	Group	n	Baseline	Endline	Diff	Ratio	DID	DOE	Ratio of Ratios
	I	1916	28	20	-8	0.71	-6	-2	0.65
BI	C	1136	20	22	2	1.10			

Table D9-2. Public spaces differences in differences (DID) and differences of endline (DOE) per Breteau index per sectors

Sector	Index	Group	n	Baseline	Endline	Diff	Ratio	DID	DOE	Ratio of Ratios
		I	689	27	25	-2	0.93	-3	-5	0.77
1		C	695	25	30	5	1.2			
	BI	I	1227	29	18	-11	0.62	-11	8	0.62
2		C	436	10	10	0	1			

Appendix E. Research paper published in Plos One

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SECTION A – Student Details

Student ID Number	Lsh1603490	**Title**	Mrs
First Name(s)	Juliana		
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Thesis Title	Evaluation of an Aedes-control intervention scaled-up under a multisectoral approach in a dengue hyperendemic city in Colombia		
Primary Supervisor	Professor James G Logan		

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RESEARCH ARTICLE

Effectiveness of an intervention for *Aedes aegypti* control scaled-up under an inter-sectoral approach in a Colombian city hyper-endemic for dengue virus

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Abstract

Aedes aegypti transmitted arboviral diseases are of significant importance in Colombia, particularly since the 2014/2015 introduction of chikungunya and Zika in the Americas and the increasing spread of dengue. In response, the Colombian government initiated the scaling-up of a community-based intervention under inter and multi-sector partnerships in two out of four sectors in Girardot, one of the most hyper-endemic dengue cities in the country. Using a quasi-experimental research design a scaled-up community-led *Aedes* control intervention was assessed for its capacity to reduce dengue from January 2010 to August 2017 in Girardot, Colombia. Reported dengue cases, and associated factors were analysed from available data sets from the Colombian disease surveillance systems. We estimated the reduction in dengue cases before and after the intervention using, Propensity Score Matching and an Autoregressive Moving Average model for robustness. In addition, the differences in dengue incidence among scaling-up phases (pre-implementation vs sustainability) and between treatment groups (intervention and control areas) were modelled. Evidence was found in favour of the intervention, although to maximise impact the scaling-up of the intervention should continue until it covers the remaining sectors. It is expected that a greater impact of the intervention can be documented in the next outbreak of dengue in Girardot.

Introduction

Aedes aegypti is the principal vector of dengue, chikungunya, Zika and yellow fever, and is now found in all continents but Antarctica [1]. *Aedes* transmitted diseases account for approximately 23% of the estimated global burden of vector-borne diseases [2] and pose a significant economic cost not only for governments in endemic countries that are responsible for case

nets employed in this study were donated by the Ministry of Health of Colombia. Colciencias URL: https://www.colciencias.gov.co/ IDRC URL: https://www.idrc.ca/ The funders had no role in the e study design, data collection and analysis, decision to publish, or preparation of the manuscript. JQ and GC received boths awards.

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management and cost of vector control activities, but also for households that have their own costs for treatment and protective measures [3–10].

The emergence and resurgence of *Aedes*-transmitted disease is associated with complex relationships between a variety of ecological, biological, and social factors of urban and peri-urban environments, all of which are particularly challenging for vector control efforts [11–13]. Ecological factors refer to climate (rainfall, humidity, temperature, etc) and the natural and man-made ecological setting (unplanned urbanization). Biological factors relate to the behaviour of the vector, *Ae. aegypti*, and transmission dynamics of these diseases (i.e the co-circulation of different serotypes) [14]. Social factors incorporate a series of influences relating to health systems, including the weakening of surveillance systems and vector control programmes[15] and health services [16] and their political context (e.g. health sector reforms, decentralization [17]), public and private services such as sanitation and sewage, garbage collection and water supply. Additionally, "macro-social" events are important, including: demographic growth and urbanization, community and household-based practices, knowledge and attitudes and how these are shaped by large-scale forces such as poverty [18,19], social inequality [20] and community dynamics including human movement [21–23].

This complexity highlights the need for setting-specific vector control approaches that combine environmental management practices with community mobilization and engagement, intersectoral and multi-stakeholder partnerships, principles of Integrated Vector Management (IVM) [24] as well as other country-specific policies such as the Integrated Management Strategy (IMS) [25]. Many community led interventions have been conducted in Asia and results indicate that the interventions reduce vector densities but evidence of impact on dengue transmission is lacking [26].

In response to the increasing threat of dengue, the Ecobiosocial/Ecohealth programme was designed by the Special Program for Training and Research in Tropical Diseases (TDR) in partnership with the International Development Research Center from Canada (IDRC) to be implemented in Asia [27] and Latin American countries (Mexico, Ecuador, Colombia, Brazil and Uruguay) over a 4-year period [28]. This initiative carried out a transdisciplinary investigation (Ecohealth approach) of ecological, biological, and social factors of dengue in urban areas, and developed and tested community-based interventions aimed at reducing *Aedes* breeding sites [29].

Specifically, a Cluster Randomized Controlled Trial (CRCT) was conducted in the dengue-hyperendemic Colombian municipality of Girardot during 2012–2014 [30]. The trial was designed to test the efficacy of long-lasting deltamethrin-treated nets (ITN), used as window/door curtains and covers on water containers, in reducing the *Ae. aegypti* density as measured through Pupae per Person Index (PPI), a proxy for adult density [30]. The study involved a cluster design comparing ten control and ten intervention areas comprising 100 households each. In control clusters, routine vector control activities (Abate, health education, and occasional public space spraying of an ultra-low volume of Malathion) were conducted. In the intervention clusters, in addition to the routine vector control activities, insecticide-treated curtains were hung over windows and doors and covers were placed over the most *Aedes*-productive water containers. Results demonstrated that PPI in intervention clusters declined by 60% after the intervention with ITN covers.

In light of the results of this trial, and following the recommendations of the 2017 WHO response strategy [2], the Colombian programme decided to extend the intervention in Girardot with the aim of achieving not only broader reduction in vector densities but also impact on dengue transmission. As a key strategy to reach the institutionalisation of the intervention and long-term viability, an intersectoral action approach was implemented among municipal entities from different sectors (health, social development, tourism, academic and education).

Here, we present the impact of an *Aedes*-vector control intervention "Girardot *Aedes*-free" in reducing the number of reported dengue cases in Girardot, Colombia, between 2015 and 2017.

Methods

Setting

The study was conducted in Girardot (4˚18′02″N 74˚48′27″W), Colombia, 134 km from the capital, Bogotá. Girardot is located 289 meters above sea level, has an annual average maximum temperature of 33.3˚C, a relative humidity of 66,38%, a mean annual precipitation of 1,220 mm, with two seasons during the year: the dry season (December-April) and the rainy season (May-October). Approximately, 105,085 inhabitants comprise around 23,885 households (97% of which are urban) distributed over 130.32 km^2. The population triples during the weekends, as its main economic revenue is tourism.

Girardot presents an eco-epidemiological and social niche favourable for sustained transmission of dengue [13,31], chikungunya and Zika. The circulation of multiple dengue serotypes has been reported [32,33]. Between 2005 and 2016, 5,928 dengue cases (residents and non-residents) were reported to the surveillance system from which 5.78% were severe. For this same period, an average of more than 500 dengue cases have been reported annually (range 81–1163). In 2013 1,103 cases were reported, 532 in 2014, and 364 in 2015. The age-groups with higher dengue cases were 5–9 and 10–14 years old (SIVIGILA 2005–2018). With respect to chikungunya the first case in Colombia was identified on September 11th of 2014 and in Girardot on December 2014. By the end of 2015 Girardot, reported 8,905 cases of chikungunya representing an annual incidence of 8,416 per 100,000 inhabitants [34] and by the end of 2016, 1,936 cases of Zika with an overall attack rate of 18.43 per 1000 residents [35].

Ae. aegypti has been reported as the principal dengue vector in Girardot [31,36] and in other dengue hyperendemic cities of Colombia (Girardot, Armenia, Arauca, Anapoima). The studies report vector productivity associated with storage of water in large and uncovered low level cement containers known as "albercas", which are estimated to account for more than 70% of pupae production [36–38].

Study design and data set

An ecological study was conducted to evaluate the impact of an intervention named Girardot *Aedes-free in* reducing notified dengue cases.

Daily dengue surveillance data for the study period January 2010 to December 2017, were obtained from the Communicable Disease Surveillance System of Girardot, Colombia (SIVIGILA) in which patients with dengue are notified according to a standard case definition of dengue [39]. Dengue cases are identified and reported by the health system as either probable dengue, probable severe dengue or, lab confirmed [39].

Anonymized was provided by the health secretary for analysis. In addition, field site access was approved by the city major (Cesar Fabián Villalba) and by the former health secretary (Manuel Díaz) and current health secretary (Erika Ramírez).

Girardot *Aedes-free* intervention

The intervention focused on four setting levels (household, school, community and institutional) where diverse actors interact and participate with different intervention components together with the control program activities. This intervention was developed, and scaled-up following an Eco health approach [29]. The scaling-up of the intervention occurred in three

Table 1. Compared characteristics of Girardot *Aedes*-free intervention and routine dengue control programme in Girardot, Colombia.

Characteristics	*Girardot Aedes*-Free	Routine dengue control program
Actions	*Household level:* Targeted intervention: insecticide-treated covers with aluminium frames or elastic band for *Aedes* productive water containers.	Daily physical inspections of water containers registering presence and absence of immature forms. Temephos in tanks. Health education for behavioral change
	School level: Community mobilization by students form public schools.	Focal study of severe dengue cases: identification of dengue positive household and surveillance of 40 surrrounding households for spatial fogging, including public spaces.
	Community level: Community mobilization by presidents of community boards.	
	Institutional level: Intersectoral committee for VBD.	
Human resources	1 field supervisor (environmental engneer). 1 field coordinator (environmental engineer). 4 field technicians (environmental engineers).	11 vector- borne technicians, 1 coordinator, 2 undergraduates as educators.
Household visits	33% of the total of households in each sector (1 and 2) with productive containers.	200 household visits per week, 40 per day in Girardot.
Indexes collected	Immature (presence/absence and pupae per person index) and adult forms.	Presence/absence of immature forms.

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distinctive phases: 1. Pre-implementation phase (planning and setting-up of activities), 2. Active implementation (action phase) and 3. Sustainability phase (follow-up activities). Table 1, describes the characteristics of the Girardot *Aedes-free* and routine vector control interventions.

For household level actions, Girardot, was divided into 4 sectors. A sector was defined as an area that included several neighbourhoods with similar ecological and sociodemographic characteristics. Each sector was divided into intervention, buffer (100 meters), and control zones. The active phase began in Sector 1 followed by Sector 2 between December 4^{th} 2015 until February 24^{th} 2017. During the active implementation phase 3,898 insecticide-treated aluminium covers were distributed in 2,935 households (1.32 covers per household) and 1,774 round covers with elastic band in 965 households (1.84 per household). Sectors 1 and 2 represent 2.52 Km^2 of the total of the urban area of Girardot (130.32 km^2) (Fig 1).

Data analysis

The effectiveness of the intervention was assessed using different quasi-experimental research designs. Differences were modelled comparing numbers of reported clinically and lab confirmed dengue cases (primary outcome) among intervention implementation points (before–after) using 1. Propensity Score Matching (PSM) [40,41], (see subsection 2 –below) and an Autoregressive Moving Average (ARMA) model and by modelling differences between numbers of dengue cases adjusted by population size of each sector among scaling-up phases (pre-implementation vs sustainability) and between treatment groups (intervention and control areas) (see subsection 3- below). Difference-in-Differences (Diff–in-Diff) method. All statistical analysis was conducted using Stata software version 15 [42].

1. Propensity Score Matching (PSM)
   The PSM consists of the following steps:

   a. Estimate the probability that a day would be treated conditional on a set of regressors. The probability is calculated by estimating the coefficients of the model $P(D=1|X)=\Lambda(XB)=\frac{e^{XB}}{1+e^{XB}}$. The coefficients were calculated by maximizing the following likelihood function $\mathcal{L}(y_1,\ldots,y_n)=\sum_{i=1}^{n} y_i \ln(\Lambda(XB))+y_i(1-\Lambda(XB))$.

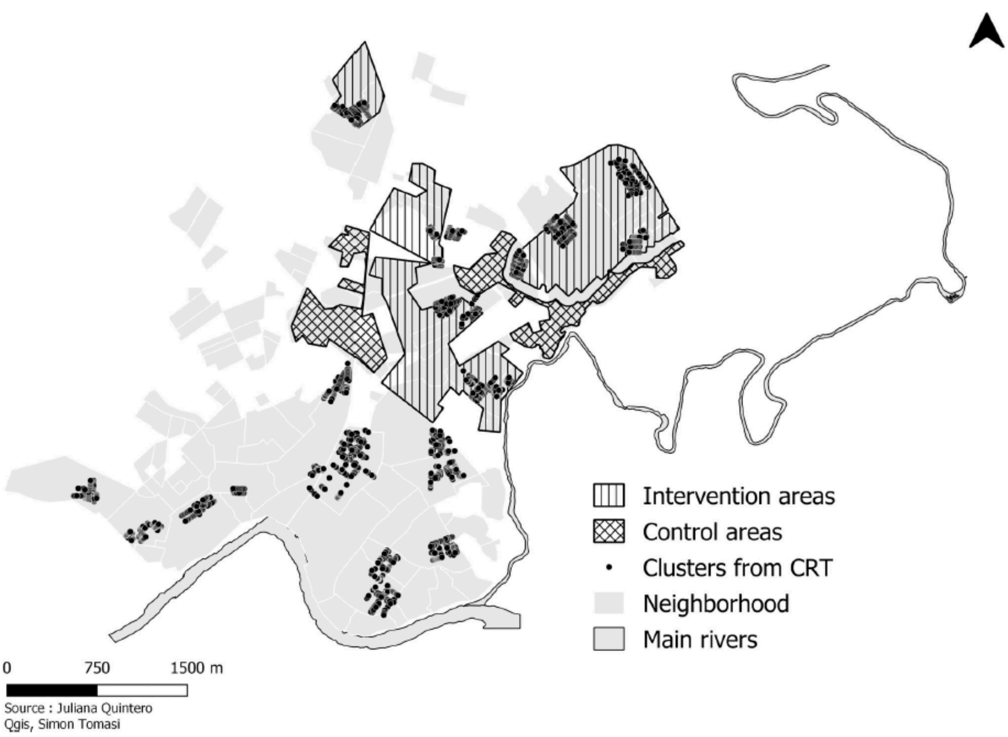

Fig 1. Map of study sectors.

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b. Check if the score is balanced.

c. Match each treated day with one not treated. For this, the following matching algorithms were used:

i. Nearest neighbour matching: Select a pair of control and treated observations that minimize the following expression

$$\mathrm{Min}\|p_i - p_j\|$$

ii. Radius: Select a pair of control and treated observations that fulfil the following expression

$$\|p_i - p_j\| < r$$

iii. Kernel (Bartlett): Each observation is matched with several observations as:

$$H(i,j) = \frac{K\left(\frac{(p_j - p_i)}{b}\right)}{\sum_j K\left(\frac{(p_j - p_i)}{b}\right)}$$

Where b is the bandwidth. All alternatives were estimated using common support, a further requirement besides independence.

d. Estimate the average impact of treatment on the treated.

2. ARMA. Because the data have a temporal structure, the estimation of an ARMA model (p, q) was performed. The number of cases is the dependent variable.

$$CN_t = \frac{e_t\beta(L)}{\alpha(L)}$$

Where L is the lag operator, i.e $x_t L^k = x_{t-k}$. And the expressions $\beta(L)$ and $\alpha(L)$ are lag polynomials of order q and p respectively. Using the autocorrelation function, partial autocorrelation and unit root tests, it was determined that the time series has an ARMA structure (3,0,3). To determine the influence of the treatment on the number of cases, a dummy variable was included in the ARMA representation, in the form:

$$CN_t = c + \alpha_1 CN_{t-1} + \alpha_2 CN_{t-2} + \alpha_3 CN_{t-3} + e_t + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \beta_3 e_{t-3} + \gamma D_t$$

After the estimation several diagnostic tests were performed. The estimate is stable, invertible, and its residuals are not autocorrelated.

3. Diff -in- Diff. Differences between numbers of dengue cases (primary outcome) among scaling-up phases (pre-implementation–sustainability) and between treatment groups (sectors 1 and 2) were estimated.

Initially dengue cases were geo-localized using the variable "address" using the SIVIGILA data set (78% of the cases were possible to localize). Then the number of dengue cases was identified in the intervention and control areas per sector using the QGIS software (V 2.18). The QGIS command 'Join attributes by location´ was used to create a new vector layer containing information on the number of cases per sectors and intervention areas [43].

A linear regression model was used to estimate the effectiveness of the intervention in the presence of associations between sociodemographic factors reported in the SIVIGILA data set (age, sex, ethnic, health insurance as a proxy of socioeconomic status). A descriptive analysis of baseline and follow-up characteristics was performed for each study group and differences between these characteristics were assessed by bivariate analysis using a test of proportions. Categorical variables were summarized as frequencies and numerical variables as means with standard deviations if normally distributed or as the medians with interquartile ranges (IQRs) if not normally distributed. The regression model used the number of cases as parameter estimates grouped per day. The effect of the intervention was tested as the effect-difference from baseline to follow up between the intervention and control areas. Significance was stated at < 0.05 level and 95% confidence intervals are reported.

Ethical considerations

International and National Standard Ethical procedures for obtaining protocol approvals as well as Informed consent were followed. The core research proposal entitled "Ecobiosocial approach for the design and implementation of a sustainable strategy for dengue vector in Colombia" was submitted for ethical clearance through the IRB of Fundación Santa Fe de Bogota. Every year the study was updated for ethics approval. The health secretary of Girardot provided and authorized the use of dengue surveillance data which was anonymized prior to access. In addition, ethical approval was obtained by the London School of Hygiene and Tropical Medicine ethics committee under the reference number 14310.

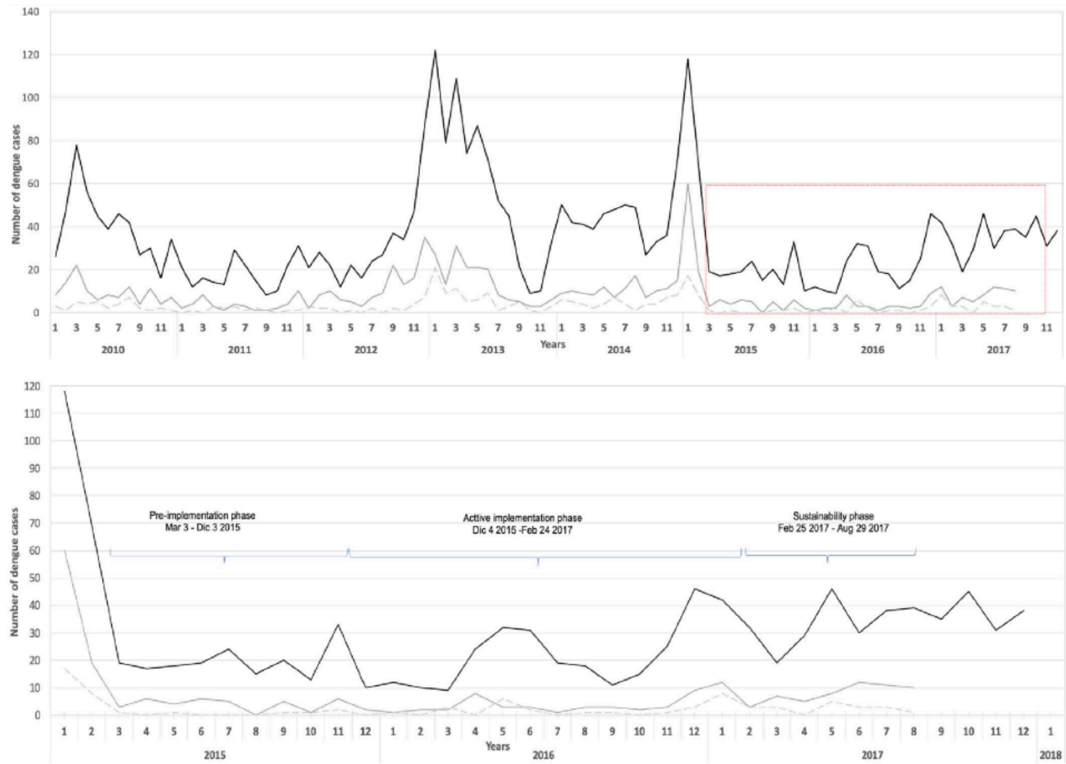

Fig 2. A. Number of reported dengue cases in Girardot, Colombia 2010–2017. The solid black line shows the number of dengue cases between 2010 and 2017 in Girardot. The solid gray line shows the number of dengue cases in intervention areas of study sectors 1 and 2. The dashed gray line shows the number of dengue cases in control areas of study sectors 1 and 2. The red square indicates the scaling-up period. **B.** Number of reported dengue cases in control and interventions areas of study sectors. Girardot, Colombia 2010–2017 The solid black line shows the number of dengue cases between 2015 and 2017 in Girardot. The solid gray line shows the number of dengue cases in intervention areas of study sectors 1 and 2. The dashed gray line shows the number of dengue cases in control areas of study sectors 1 and 2.

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Results

Description of notified dengue cases in Giradot, 2010–2017

Between 2010 (1st epidemiological week) and 2017 (33rd epidemiological week), 3,193 suspected dengue cases were reported to the surveillance system of Girardot, of which 99.6% were clinically classified as dengue. During this period a mean of 1.93 dengue cases were reported per day (range 1 to 14) although only 198 (6.2%) were laboratory-confirmed. Fig 2A, shows three outbreaks, over the course of 8 years. During 2010, 487 dengue cases were reported, 708 cases in 2013 and 532 in 2014.

Slightly more dengue cases were reported in men than in women (1,690, 52,9%). The mean age was 21.6 years, and 55.3% (1768) among children younger than 16 years old. A greater number was reported in age-groups 0–5 (587) and 6–10 years old (720).

Table 2. Figures of dengue cases in intervention and control areas during baseline and follow-up surveys, Girardot 2015–2017.

Sectors	1				2				All sectors			
Areas	Intervention		Control		Intervention		Control		Intervention		Control	
Population	9,538		3,931		14,430		2,118		23,968		6,049	
Number of dengue cases (*)	47 (492.76)		22 (559.65)		42 (291.06)		10 (472.14)		89 (371.32)		32 (529.01)	
Time of Survey	BL	FU	BL	FU	BL	FU	BL	FU	BL	FU	BL	FU
Number of dengue cases per sector	11	36	3	19	14	28	5	5	25	64	8	24
Incidence per 100,000 inhabitants	115.32	377.43	76.31	483.33	97.02	194.04	236.07	236.07	104.30	267.02	132.25	396.75
Mean age	25.63		32.63		28.66		23.8		27.06		29.87	
SD	24.36		25.26		24.64		26.69		24.40		25.62	
Sex												
F	22 (46.80)		10 (45.45)		16 (14.28)		5 (50.00)		38 (42.69)		15 (46.87)	
M	25 (53.19)		12 (54.54)		26 (61.90)		5 (50.00)		51 (57.30)		17 (53.12)	

BL: baseline, FU: Follow-up, SD: Standard deviations, F: female, M: male.

* Incidence per 100,000 inhabitants.

https://doi.org/10.1371/journal.pone.0230486.t002

Description of notified cases in Giradot, during scaling-up of the intervention

During the period of March 2015 to August 29 2017 (Setup phase: baseline, Active phase: implementation of intervention and Sustainability phase: follow-up) 702 dengue cases were reported in the SIVIGLA of Girardot. Twenty-eight percent of these (n = 194) were from the study sectors, 69 dengue cases were reported during baseline and follow-up in Sector 1, and 52 cases in Sector 2. During baseline 11 cases were reported in the intervention area of Sector 1, compared to 3 cases in the control area.

A similar situation was observed for Sector 2, where 14 dengue cases were reported in the intervention area, compared to 3 cases in the control area. Dengue incidence was generally higher in Sector 1 (526.2 per 100.000 inhabitants) compared to Sector 2 (381.6 per 100.000 inhabitants). For all sectors the incidence was higher in the control area (529.01 per 100.000 inhabitants) than intervention area (371.32 per 100.000 inhabitants). There was an increase in dengue incidence reported in both intervention and control areas from baseline to follow-up. The increase in dengue incidence per 100.000 inhabitants for all sectors was greater in the control areas (an increase of 396.75 cases per 100.000 inhabitants) than in intervention areas (an increase of 267.02 cases per 100.000 inhabitants). In Sector 1, the increase in dengue incidence was higher in control areas (an increase of 483.33 cases per 100.000 inhabitants) than in intervention areas (an increase of 377.43 cases per 100.000 inhabitants). In Sector 2 the incidence in control areas did not change from baseline to follow-up (236.07), but the incidence from baseline to follow-up in the intervention area increased almost two-fold (Table 2).

Table 2, describes the distribution of dengue reported cases in the intervention and control areas during baseline and follow-up surveys only (n = 122).

Effectiveness

The PSM analysis indicates that the intervention resulted in a decrease of an average of between 0.12 (-0.25,0.01) and 0.26 (-0.42, -0.10) cases of dengue daily (1.82 cases per week or 7.8 cases per month or 95 cases per year) in Girardot (Table 3). By the same means, the time series analysis suggests that the treatment on average decreased the number of dengue cases by 0.27 cases daily (Table 4).

Table 3. Average treatment effects estimation using Radius and Kernell matching method.

Matching method	Number of treatments	Numbers of controls	ATT	95% CI	t
Kernel (attk)	215	1414	-0.122	-0.25,0.01	-1.830
Radius (attr)	215	1414	-0.263	-0.42, -0.10	-3.170

Number of observations = 1629 Replications = 2500, ATT: Average treatment effect on the Treated group, CI: Confidence Interval.

https://doi.org/10.1371/journal.pone.0230486.t003

The Diff-in-Diff estimator reports an increase of 0.065 dengue cases daily (0.455 per week, 1.95 per month) (Table 5), but when calculating the differences in incidences rates and rate ratios during sustainability (follow-up phase) among intervention and control areas of both sectors (see Table 2), an incidence rate difference of– 0.0129 (95% CI -0.00179- -0.00078) and an incidence rate ratio of 0.674 (95% CI 0.577–0.786) are observed.

Discussion

The principal goal of any dengue intervention is to reduce disease incidence and preferably transmission by reducing human exposure. *Ae. aegypti* control remains the primary tool available to achieve the latter goal. Several systematic reviews published in the last decade [26,44–47] have reported the impact of dengue vector control. They concluded that the most effective are community-based interventions that combine community and social mobilization, participation with local government control services, joint collaboration with local services, with environmental management or clean-up campaigns, water covers and window screens using insecticide-treated nets, and use of larvicides.

These reviews indicated that the effect of a dengue vector control interventions is principally measured using entomological parameters (indicators of vector infestation) however these indicators do not always accurately reflect dengue transmission [48,49]. The studies that include epidemiological risk indicators to determine the effect of a dengue vector control intervention mainly use interrupted time series, propensity score matching and classic, spatial, and Bayesian statistical analysis, [50–52]. These are preferably selected as costs, resource demands, and contamination effects are factors that impede the feasibility of conducting alternative experimental designs.

Our study used a quasi-experimental design to assess the impact of a dengue vector control intervention in Girardot, Colombia, developed with local stakeholders and implemented following an ecohealth approach [26].

Table 4. Number of dengue cases after intervention estimated by Arma model.

Variables	Coefficient	95% CI	p-value
Constant	1.86	1.50, 2.22	<0.0001
Intervention	-0.27	-0.95, 0.41	0.436
ARMA parameters			
AR (1)	1.68	1.25, 2.10	<0.0001
AR (2)	-0.68	-1.10, -0.261	0.002
MA (1)	-1.54	-1.97, -1.11	<0.0001
MA (2)	0.54	0.19,0.89	0.002
MA (3)	0.01	-0.06,0.09	0.721
Sigma	1.23	1.20,1.26	<0.0001

AR: Auto Regressive, MA: Moving Average, CI: Confidence Interval.

https://doi.org/10.1371/journal.pone.0230486.t004

Table 5. Difference-in-Difference estimation results from sectors 1 and 2, Girardot.

Outcome variable	Dengue cases	Standard Error	p-value	95% CI
Baseline				
Control	0.929			
Treated	0.989			
Diff (T-C)	0.060	0.069	0.387	-0.0763538 0.1961956
Follow-up				
Control	0.950			
Treated	1.075			
Diff (T-C)	0.125	0.086	0.151	
Diff-in-Diff	0.065	0.1120	0.557	-0.152547 0.2818859

R-square: 0.06, Means and Standard Errors are estimated by linear regression, Number of observations in the Diff-in-Diff: 173. Adjusted by age, sex, season and health insurance.

https://doi.org/10.1371/journal.pone.0230486.t005

When analyzing the series of dengue cases, it is observed that outbreaks occur every three years and importantly, the number of cases per season differed, more cases were reported in the dry seasons than in the rainy seasons. Although the dry season includes 7 months (December–February and June–September), and the rainy season includes only 5 (March–May and October–November), the former still has a higher mean number of cases per month. High temperatures, relative humidity, precipitation are well known factors that related to dengue transmission [53,54]. These factors facilitate *Ae. aegypti*, population growth, but in Girardot the increase in tourism (presence of susceptible populations, higher population density) during the dry seasons is also an important factor that favors virus transmission and can have an effect on the increase of dengue cases reported during this season.

Despite low dengue transmission reported during the intervention phases the results indicate that the areas covered with the intervention reported a reduced dengue incidence over the 6 to 12 months compared to control areas, although in both areas the incidence increased. The difference in dengue incidences seen per sector after the implementation phase may be due to the reduced use of container covers over time. Follow-up of sector 1 was performed 12 months after intervention implementation compared to sector 2, where follow-up was performed after 6 months. A variety of studies argue that the use of an intervention tends to decrease over time [55–57]. As with any vector control measure, a consistent level of compliance is needed by household members to gain sustainability of the intervention [58,59]. There is a need for identifying factors capable of achieving permanent changes in human behavior. Moreover, the percentage of productive container coverage per sector did not reach 100% (Sector 1, 39.54% of coverage and Sector 2, 50.39% of coverage). High coverage is needed for the intervention to have a broader impact [55–57]. The main reason for the limited coverage was the inaccessibility of participant houses, even after three visits. It is important to point out that Girardot is a touristic site and many of the houses are the "second residences" of inhabitants of other cities (primarily Bogotá) for recreational purposes [37].

More than half of the study population comprised schoolchildren who attend school during the daytime. Schoolchildren participated in mobilization activities but not breeding-site interventions nor were screens for classrooms implemented in schools. Another important age group are young men and women who spend significant proportions of time in places of work and in commercials sites, neither of which were included as interventions sites. A growing body of evidence [22,60–62]has shown that human movement is an important consideration when analysing the effectiveness of vector interventions and understanding dengue epidemiology. Previous studies have shown that transmission of dengue virus appears to be largely driven by infections centered in and around the home, with the majority of cases related to one another occurring in people who live less than 200 meters apart, supporting a role for targeted vector control around the residences of detected cases [63].

Furthermore, it is important to consider other locations where individuals tend to gather and spend significant amounts of time, as they may play an important role in the virus cycle. Sites such as schools pose a risk of transmission as there may be abundant breeding containers for *Aedes* vectors and will contain an aggregation of students during the daytime [64–66].

Defining effectiveness is one of the elements for scaling-up an intervention into public health policies. However, other criteria are equally important, including acceptability, reach, adoption, ease of delivery, alignment with local policies and cost [67–69]. Further analysis of the fidelity [70–72] of the intervention and cost effectiveness are being conducted to have a broader picture for decision making.

Limitations

Using secondary quantitative information of notified dengue cases from SIVIGILA possess several challenges, which has been evident in studies in other countries such as Colombia [32,73–75]. The surveillance system only captures symptomatic patients who sought treatment at health care services, and are registered with a residential address that is not necessary the location of dengue transmission. In addition, no specific serotype information is reported.

Another limitation is the available spatial information (road network, neighbourhoods and blocks) and the address and neighbourhood fields in the SIVIGILA database required for identifying dengue cases. The address and neighbourhood fields are not standardized and an important work of filtering information was needed to decrease the error when localizing each dengue case by sectors and intervention and control areas; but, seventy eight percent of dengue reported cases were able to geo-locate, underestimating the true incidence.

In addition, during intervention dengue incidence decreased during this period following the trend of dengue peaks in Girardot and elsewhere every three years. It would be expected that at higher incidence of dengue the impact of intervention may have been higher than the one reported in our follow up. The decrease of dengue cases during the scaling-up phases can be a long-term result from previous interventions carried out in Girardot since 2012 combined with enhanced vector control actions implemented by the local health authorities due to the re-emergence of chikungunya and Zika viruses.

Conclusion

The aim of dengue vector control is to maintain *Ae. aegypti* populations below or close to minimal transmission thresholds, slow the force of dengue-virus transmission, and reduce sequential infections with different serotypes. Here an intervention was evaluated for its capacity to reduce notified dengue cases by targeting the most productive dengue vector containers. The results indicate a reduction in dengue incidence compared to matched controls sites, although this is probably an underestimated of the true potential of the intervention. Greater coverage, reaching other sectors and other high-risk transmission areas (Public spaces such as school and commercial sites), and improved surveillance system are required for maximising the effect of the intervention.

Supporting information

S1 Data. Girardot dengue cases 2010 2017.
(XLSX)

S2 Data. Data base for Diff in diff estimation.
(XLSX)

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Appendix F. Interview guide

GUíA ENTREVISTAS

Datos entrevistas
Fecha: Código asignado:
Datos entrevistado
Nombre y apellido: Edad: Sexo: Ocupación: Con quien vive el entrevistado: Barrio:

Pregunta	***Tiempo***	***Palabras claves respuesta***
Intervención		
¿Cómo le ha parecido el proyecto?		
¿Le parece relevante la intervención?		
¿Cómo fue la intervención?		
¿Es práctico su uso? ¿Por qué?		
¿Su instalación fue sencilla? ¿Qué le cambiaria?		
¿Cuáles son las ventajas de estas tapas?		
¿Cuáles son las desventajas?		
Participación		
¿Cómo fue su participación? ¿Qué actividades realizo?		
¿Cuál ha sido la importancia de su participación en el desarrollo del proyecto?		

¿Quién lidera el proyecto?		
¿Qué mas personas o instituciones han participado en el proyecto?		
De estas otras instituciones o personas que han participado ¿Como han ayudado al proyecto?		
Cambio de comportamiento en hogar		
¿Cómo han cambiado las prácticas de prevención y control de mosquitos desde la intervención en su hogar?		
Factores facilitadores y limitantes		
¿Cuáles han sido los elementos que facilitaron para que el proyecto se llevará a cabo? (contexto, político, económico)		
¿Cuáles han sido elementos que dificultaron el desarrollo del proyecto?		
¿Qué le cambiaria al proyecto?		
Información de contacto o posibles contactos		

Appendix G. Categories of analyses per frameworks

Categories	Frameworks			
	ExpandNet	**MRC**	**Fidelity**	**Ecohealth**
Innovation	Innovation Correct attributes	Intervention Description and causal assumption (logic model)	Intervention Components or descriptors or essential elements	Intervention
Resource team	Resource team	-	-	Multisectoral collaboration and engagement of multiple types of stakeholder Implementers
User organisation	User organisation	-	-	-
Environment	Environment	Context	Context	Ecosystem
Scaling-up strategy	Scaling up strategy	-	-	Participatory approach Transdisciplinary research
Fidelity	-	Implementation process and what is delivered	Adherence Coverage Duration Frequency Adaptation	-
Mechanisms	-	Mechanisms of impact or mediators	Moderators: Quality of delivery Participant responsiveness Setting	-

Appendix H.

Table G-1. Partnership analysis tool (VPAT)

Dominios		0	1	2	3	4
		Totalmente desacuerdo	**Desacuerdo**	**No esta seguro**	**De acuerdo**	**Totalmente de acuerdo**
Necesidad de asociación						
1	Se identifica la importancia del comité y del trabajo conjunto					
2	Hay un objetivo claro en el comité					
3	Existe una comprensión de las líneas de acción y compromisos entre los actores					
4	Los actores están dispuestos a compartir ideas y recursos para cumplir los objetivos					
5	Se identifican los beneficios del trabajo conjunto					
TOTAL						
Actores y asociación						
6	Los actores comparten intereses y enfoques					
7	Hay una historia de trabajo conjunto entre los actores					
8	La asociación es bien vista o trae beneficios adicionales a los actores					
9	Hay una variedad en los actores que hace que exista una comprensión integral del problema					

TOTAL						
Logrando que la asociación funcione						
10	Los directivos o jefes de cada organización apoya el comité					
11	Los actores tienen las habilidades para el trabajo conjunto					
12	A partir de las acciones realizadas se mejoran las capacidades de los actores					
13	Los roles, responsabilidades y expectativas están definidas y todos los actores las identifican					
14	La administración, comunicación y el proceso de decisión es simple					
15	El liderazgo es conjunto y se promueven las acciones concentadas					
TOTAL						
Planeación de las acciones colaborativas						
16	Todos los actores están involucrados en la planeación y priorización de las acciones					
17	Los actores tienen la tarea de comunicar y promocionar el comité en sus organizaciones					
18	Algunas actividades van mas allá de las actividades tradicionales que hacen las organizaciones					
19	La toma de decisiones es participativa e incluyente					
TOTAL						

Implementación de las acciones						
20	Los procesos/ actividades son comunes para todos los actores					
21	Existe una inversión de tiempo, personal o equipamiento para el trabajo conjunto por parte de todos los actores					
22	Las acciones tienen un valor para las instituciones					
23	Existen oportunidades para la inclusión de personal de diferentes organizaciones					
TOTAL						
Minimizando las barreras del trabajo conjunto						
24	Se han discutido las diferencias entre los actores y sus objetivos					
25	Existe un grupo de personal calificado y comprometido para la realización de las acciones					
26	Existen espacios para compartir información y resolver diferencias entre los actores					
27	Hay cabida para que se expresen puntos de vista diferentes					
TOTAL						
Continuación del trabajo conjunto						
28	Existen procesos para reconocer los logros colectivos y la contribuciones					

29	El comité puede demostrar o documentar los resultados del trabajo colectivo					
30	Existe una clara necesidad y compromiso de continuar la colaboración a mediano plazo					
31	Hay recursos disponibles (internos o externos) para continuar la asociación					
32	Hay una manera de revisarlos actores y traer nuevos miembros o eliminar algunos					
TOTAL						

Appendix H2. Perceived participation survey

EVALUE LOS ACTORES DEL COMITE INTERSECTORIAL

1 Participación del actor: Evalue de 1 a 5, que tanto cada actor participa en el comité. Participación se entiende como la asistencia a las reuniones, la discusión y planteamiento de actividades.

2 Realización de actividades: Dicho actor ha realizado actividades para la prevención y control de las ETVs, en el marco del comité ?

3 Evalue la representación y delegación: Evalue si los asistentes (delegados o representantes de cada institución) es la persona adecuada para la toma de decisiones y el funcionamiento del comité.

INSTITUTION	**Participación del actor**					**Realización de actividades**		**Adecuada representación y delegación**	
	1	**2**	**3**	**4**	**5**				
	Nula	**Nula-Pasiva**	**Pasiva**	**Pasiva-Activa**	**Activa**	**Si**	**No**	**Si**	**No**
Alcaldía Municipal									
Secretaría de Salud									
Secretaría de Educación									
Secretaría de Tránsito y Transporte de Girardot *									
Fundación Santa Fe de Bogotá									
Oficina Asesora de Planeación									
Corporación PRODESARROLLO									
Instituto Municipal de Turismo									
ASOJUNTAS									

Juntas de Acción Comunal									
Cámara de Comercio de Girardot									
Terminal de Transportes de Girardot									
Diócesis de Girardot									
Asociación de Iglesias Cristianas de Girardot									
Club Rotario Girardot *									
Veesagir - Veeduría									
Instituciones educación superior y técnica									
Universidad Piloto									
UNAD									
Uniminuto									
Universidad de Cundinamarca									
EPS e IPS									
Nueva Clínica San Sebastián - NCSS									
Dumian									
Famisanar									
EPS Comparta									
EPS Sanitas									
Salud Vida									
Empresas de servicios públicos									
Acuagyr									
Serambiental									

Instituciones educación primaria y secundarias									
I.E Policarpa Salavarrieta									
Instituto Kennedy									
Instituto Educativo Atanasio Girardot – IETAG									

Appendix H3. Semi-structured Interview guide

GUIA DE ENTREVISTA INTEGRANTES COMITÉ		
Fecha Institución		Código Cargo
Necesidad de asociación	**Audio**	**Respuesta**
¿Hay un objetivo claro en el comité? ¿Todos los integrantes lo identifican?		
¿Usted y los demás integrantes identifica los beneficios del trabajo conjunto y de ser parte del comité?		
¿La asociación es bien vista o trae beneficios adicionales a los actores?		
Logrando que la asociación funcione		
¿Los actores que integran el comité, tienen habilidades para el trabajo conjunto ?		
¿Los integrantes del comité son personas con las capacidades y comprometido para la realización de las acciones?		
Planeación de las acciones colaborativas		
¿Cómo es la planeación y priorización de las acciones?		
¿Cómo son los procesos de comunicación y difusión de las acciones de comité?		
Implementación de las acciones		
¿Qué actividades de han llevado a cabo?		
¿Qué instituciones invierten tiempo, personal o equipamiento para el trabajo conjunto? ¿porque otras instituciones no lo hacen?		
¿El comité puede demostrar o documentar los resultados del trabajo colectivo? ¿Cómo se han documentado y por que medios se han divulgado los resultados del comité?		
Minimizando las barreras del trabajo conjunto		
¿Qué opinión tiene al respecto de los integrantes del comité? (representación y delegación)		
¿ Como es el flujo de información y como se resuelven las diferencias entre los actores?		
Continuación del trabajo conjunto		

¿Cómo puede ser el comité sostenible?		
¿Existe un compromiso de continuar la colaboración a mediano plazo?		
¿Hay recursos disponibles (internos o externos) para continuar la asociación		
¿Qué estrategias se deberían implementar para lograr el liderazgo local?		

Appendix H4. VPAT survey results

	Statements	Percentage (n=13)					Median score	% of the total score	Total
		0 Strongly disagree	1 Disagree	2 Not sure	3 Agree	4 Strongly agree			
A	**Determining the need for the partnership**								
1	There is a perceived need for the partnership in terms of areas of common interest and complementary capacity			7.69	46.15	46.15	3.38	84.62	4
2	There is a clear goal for the partnership			7.69	46.15	46.15	3.38	84.62	4
3	There is a share understanding of, and commitment to this goal among all potential partners			23.08	23.08	53.85	3.31	82.69	4
4	The partners are willing to share some of their ideas,resources, influence and power to fulfill the goal		7.69	23.08	46.15	23.08	2.85	71.15	4
5	The perceived benefits of the partnership outweigh the perceived costs				58.33	41.67	3.15	78.85	4
	TOTAL						**16.08**	**80.38**	**20**
B	**Choosing partners**								
6	The partners share common ideologies,interests and approaches		7.69	15.38	46.15	30.77	3.00	75.00	4
7	There is a history of good relations between the partners		15.38	7.69	61.54	15.38	2.77	69.23	4
8	The coalition brings added prestige to the partners individually as well as collectively		7.69	23.08	30.77	38.46	3.00	75.00	4

9	There is enough variety among members to have a comprehensive understanding of the issues being addressed		15.38	23.08	46.15	15.38	2.62	65.38	4
	TOTAL						**11.38**	**71.15**	**16**
C	**Making sure partnerships work**								
10	The managers in each organisation support the partnership	7.69	7.69	23.08	30.77	30.77	2.69	67.31	4
11	Partners have necessary skills for collaborative action		15.38	30.77	23.08	30.77	2.69	67.31	4
12	There are strategies to enhance the skills of the partnership through increasing the membership or workforce development		7.69	23.08	46.15	23.08	2.85	71.15	4
13	The roles, responsibilities and expectations of partners are clearly defined and understood by all other partners		7.69	38.46	46.15	7.69	2.54	63.46	4
14	The administrative, communication and decision-making structure of the partnership is simple as possible		7.69	15.38	15.38	61.54	2.54	63.46	4
15	The leadership is joint and concerted actions are promoted		7.69	23.08	53.85	15.38	2.54	63.46	4
	TOTAL						**15.85**	**79.23**	**24**
D	**Planning collaborative action**								
16	All partners are involved in planning and setting priorities for collaborative action		23.08	23.08	38.46	15.38	2.46	61.54	4
17	Partners have the task of communicating and promoting the coalition in their own organisations		15.38	38.46	38.46	7.69	2.38	59.62	4
18	Some staff have roles that cross the traditional boundaries that exist between agencies in the partnership		15.38	38.46	38.46	7.69	2.38	59.62	4
19	There is a participatory decision-making system that is accountable, responsive and inclusive		7.69	23.08	61.54	7.69	2.69	67.31	4
	TOTAL						9.92	62.02	16

E	**Implementing collaborative action**								
20	Processes that are common across agencies such as referral protocols, service standard, data collection and reporting mechanisms have been standarised	7.69	15.38	30.77	38.46	7.69	2.23	55.77	4
21	There is an investment in the partnership of time, personnel, materials and facilities	7.69	23.08	38.46	23.08	7.69	2.00	50.00	4
22	The action is adding value (rather than duplicating services) for the community, clients or the agencies involved in the partnership	7.69		38.46	38.46	15.38	2.54	63.46	4
23	There are regular opportunities for informal and voluntary contact between staff from the different agencies and other members of the partnership	7.69	7.69	23.08	46.15	15.38	2.54	63.46	4
	TOTAL						**9.31**	**58.17**	**16**
F	**Minimizing the barriers to partnerships**								
24	Differences in organisational priorities, goals and tasks have been addressed	7.69	7.69	15.38	38.46	30.77	2.77	69.23	4
25	There is a core group of skilled and committed (in terms of the partnership) staff that has continued over the life of the partnership			7.69	53.85	38.46	3.31	82.69	4
26	There are formal structures for sharing information and resolving demarcation disputes		7.69	15.38	30.77	46.15	3.15	78.85	4
27	There are strategies to ensure alternative views are expressed within the partnership				38.46	61.54	3.62	90.38	
									4
	TOTAL						**12.85**	**80.29**	**16**
G	**Reflecting on and continuing the partnership**								
28	There are processes for recognising and celebrating collective achievements and/or individual contributions			15.38	53.85	30.77	3.15	78.85	4

29	The partnership can demonstrate or document the outcomes of its collective work				53.85	46.15	3.46	86.54	4
30	There is a clear need and commitment to continuing the collaboration in the medium term			23.08	38.46	38.46	3.15	78.85	4
31	There are resources available from either internal or external sources to continue the partnership	15.38	15.38	38.46	15.38	15.38	2.00	50.00	4
32	There is a way of reviewing the range of partners and bringing in new members or removing some			30.77	53.85	15.38	2.85	14.23	4
	TOTAL						**14.62**	**73.08**	**20**

Appendix H5. Lines of actions, activities implemented by sectors of the multisectoral action committee during 2015-2017

Year	Line of action	Activities	Institutions	Sector
2015	Information and communication	Design and dissemination of committee's newsletter	FSFB	Research
	Training	Training of VBD technicians	FSFB	Research
	Research	Design of a research seedbed	UNAD	Education
		Research course with primary school teachers	FSFB Secretariat of Education	Research Education
	Research	Development and implementation of the Girardot Aedes-Free intevetion	FSFB Community members Public Local Schools	Research

2016	Information and comunication	Design and dissemination of the committee newsletter	FSFB	Research
		Drafting and submission of the steering committe agreement to the municipal council.	FSFB Secretariat of Health	Research Health
		Socialization of information with Girardot press	UNAD	Education
	Education	Students will carry out information and communication actions in VBD as part of the mandatory social service.	FSFB Public schools	Research Education
		Design of an informative mural and design of a school environmental project on VBD	FSFB Public schools	Research Education
		Development of Research Seminar Dissemination of information about dengue as part of the School Environmental Project (PRAE in Spanish). In addition, the students set out to be the first school in	UNAD Public schools	Education

		Girardot and in Colombia "Free of dengue, Chikungunya and Zika”		
	Research	Research development of the Girardot *Aedes -Free* intervention: socialization of results of the public policy component and economic analysis	FSFB	Research
		Establishment of a seedbed in public health research	UNAD	Education
2017	Administrative	Discussion and definition of internal regulations of the steering committee	All members	
	Actions in public spaces	3 days garbage collection, cleaning of rain water drains in different neighborhoods and dissemination of vector and arbovirus prevention information	Health secretariat FSFB Acuagyr (sewage services)	Health Education Research Public services

		Serambiental (garbage collection services)	
Research	Research Undergraduate thesis in pharmacy: good clinical practices for dengue treatment prescription	FSFB UNAD	Research Education
Information and communication	Design and distribution of flyers regarding vector prevention and control for tourists	FSFB Tourism of Institute Transport terminal	Research Tourism Transportation
	Workshops with community leaders	UNAD	Education