Taking innovative vector control interventions in urban Latin America to scale: lessons learnt from multi-country implementation research

Juliana Quintero^a , Tatiana García-Betancourt^a , Andrea Caprara^b , Cesar Basso^c,
Elsa Garcia da Rosa^d, Pablo Manrique-Saide^e, Giovanini Coelho^f , Gustavo Sánchez-Tejeda^g,
Felipe Dzul-Manzanilla^g , Diego Alejandro García^h, Gabriel Carrasquilla^a , Eduardo Alfonso-Sierraⁱ ,
Cynthia Monteiro Vasconcelos Motta^b, Johannes Sommerfeld^{j,k} , and Axel Kroeger^j

^aDivision of Public Health, Fundación Santa Fe de Bogotá, Bogotá, Colombia; ^bCentro de Ciências da Saúde, Universidade Estadual do Ceará, Fortaleza, Brazil; ^cDepartamento de Protección Vegetal, Facultad de Agronomía, Universidad de la República, Montevideo, Uruguay; ^dDepartamento de Parasitología Veterinaria, Facultad de Veterinaria, Universidad de la República, Salto, Uruguay; ^eDepartamento de Zoología, Campus de Ciencias Biológicas y Agropecuarias, Universidad Autónoma de Yucatán, Mérida, México; ^fNational Dengue Control Programme, Secretariat of Health Surveillance, Ministerio de Saude, Brasília, Brazil; ^gCentro Nacional de Programas Preventivos y Control de Enfermedades, Secretaría de Salud, Mexico, México; ^hMinisterio de Salud y Protección Social, Subdirección de Enfermedades Transmisibles, Bogotá, Colombia; ⁱCentre for Medicine and Society/Physical Anthropology, University of Freiburg, Freiburg, Germany; ^jSpecial Programme for Research and Training in Tropical Diseases (TDR), World Health Organization, Geneva, Switzerland; ^kCentre for Health Development, World Health Organization, Kobe, Japan

ABSTRACT

Prior to the current public health emergency following the emergence of chikungunya and Zika Virus Disease in the Americas during 2014 and 2015, multi-country research investigated between 2011 and 2013 the efficacy of novel *Aedes aegypti* intervention packages through cluster randomised controlled trials in four Latin-American cities: Fortaleza (Brazil); Girardot (Colombia), Acapulco (Mexico) and Salto (Uruguay). Results from the trials led to a scaling up effort of the interventions at city levels. Scaling up refers to deliberate efforts to increase the impact of successfully tested health interventions to benefit more people and foster policy and program development in a sustainable way. The different scenarios represent examples for a 'vertical approach' and a 'horizontal approach'. This paper presents the analysis of a preliminary process evaluation of the scaling up efforts in the mentioned cities, with a focus on challenges and enabling factors encountered by the research teams, analysing the main social, political, administrative, financial and acceptance factors.

Abbreviations: TDR-IDRC: Special Programme of Training in Tropical Medicine-International Development Research Center; MoH: Ministry of Health; ITS: Insecticide Treated Screens; VS: Vivienda Segura; LLIN: long-lasting insecticidal-nets; NGOs: Non Gubernmental Organizations; CONACYT: Consejo Nacional de Ciencia y Tecnología; WHO: World Health Organization; PAHO: Panamerican Health Organization

KEYWORDS

Aedes aegypti; vector control; prevention; scaling up; process evaluation; Latin America

Background

With the emergence of chikungunya and zika virus disease in the Americas during 2014 and 2015, the dengue transmitting vectors *Aedes aegypti* and – to a lesser extent – *Aedes albopictus* have gained increasing importance and triggered a significant media reaction. The prevention of these diseases through efficient and effective vector control tools and operations is currently a major public health concern in the affected countries as well as at global level [1–4]. Conventional methods of vector management, as practiced in our target countries and elsewhere include particularly larviciding of domestic water containers and cleaning up campaigns against small discarded containers in and

around houses [5–7]. Little or no attention was paid to the identification of the most important water container types through pupal surveys producing adult mosquitos, which should be a priority target for vector control interventions [8]. In view of the continuing dengue threat and enhanced by the newly emerging *Aedes* born disease (Zika, chikungunya, Yellow Fever), a research programme was designed and the efficacy of novel *Aedes aegypti* intervention packages was tested which included the identification and control of productive container types [8], window screening with insecticide treated materials, covering of major water tanks and establishing a partnership among vector control services, the local communities and other

actors (see below) [9]. The efficacy testing was done from 2011–2013 through cluster randomized controlled trials in four Latin-American cities: Fortaleza (Brazil); Girardot (Colombia), Acapulco (Mexico) and Salto (Uruguay) following a research initiative in Latin America supported by the Special Programme for Tropical Disease and Training (TDR-WHO) [9]. The results attracted the interest of governments and civil society institutions in the four countries to replicate the approach in their own environment at a large scale and to document both the process and the results of the interventions. Therefore, scaling up the experience was planned to be extended to large geographic areas and as a first attempt to introduce the novel tools and strategies into national control programmes accompanied by operational research.

Scaling up process involves rarely a mechanical duplication of innovations, rather, it requires working on several fronts and making a number of strategic choices, considering the nature of the interventions being scaled up, the role of various partners, the political and socio-cultural context and financing [10–13]. Scaling refers to deliberate efforts to increase the impact of successfully tested health interventions to benefit more people and foster policy and program development on a sustainable basis [14]. Innovation is understood as a number of interventions that include new technologies, clinical practice, educational components or community initiatives and also the management processes necessary to carry out a successful implementation [14].

Three types of scaling up have been identified [14]: expansion or replication (horizontal), policy/legal and institutional (vertical), and diversification. The first type of scaling is based on an innovation that moves to another context. It refers to an innovation that is replicated in a different geographical area and stretches on the basis of a broader service or a new population group. The second type (vertical scaling) is given when a Government makes a formal decision to adopt an innovation at national or sub-national level and institutionalizes it by public policy or legal actions. Therefore, systems and structures are adapted, resources are redistributed to create an institutional mechanism that will ensure the sustainability of the intervention. The third type of scaling (diversification or functional scaling up) consists of adding new interventions to an existing package [14].

In the scaling up process of novel *Aedes*-Vector control tools and strategies was initiated in the following way: The Ministry of Health (MoH) of *Brazil*, was particularly interested in the vector protection by window/door screens which had been tested previously in *Mexico* [15,16] and provided 1.2 Million USD as a start up capital to two large cities of Brazil (Goiana and Belo Horizonte) for applying the intervention. In *Colombia* in a highly endemic city (Girardot) several governmental institutions (including the MoH, local hospitals as well as state and municipal secretariats of health) and the

civil sector (including local universities, chamber of commerce, tourism industry, community organizations) wanted to implement the previous successful experience of covering the most productive containers (wash tanks) with a novel device at scale. In *Mexico*, the vector control intervention with insecticide treated window and door screens (ITS) as part of the national strategy ‘Vivienda Segura’ (secure home, VS) [17] – interested policy makers and the civil society of the peninsula of Yucatan (State Ministry of Health, Ministry of Education, local authorities and enterprises) in attracting resources for implementing the measures in the State Capital Merida, *Uruguay*, City of El Salto, within the frame of an intersectoral collaboration involved public institutions (Ministry of Public Health, Municipality of Salto and University of the Republic), local neighbourhood committees, children associations, Non-governmental Organizations (NGOs), schools, polyclinics and others, to scale-up the experience of the preceding successful antivectorial intervention based on waste disposal addressed by the community [18].

In this paper we present the prospects and limitations of the scaling up process of a novel *Aedes aegypti* vector control program in four Latin American countries showing important political, administrative, financial and acceptance factors during the implementation of large scale interventions.

Methods

Study area and interventions

The scaling up process was implemented in Belo Horizonte and Goiania (Brazil), Girardot (Colombia), Merida (Mexico) and Salto (Uruguay). The characteristics of the five cities are summarized in Table 1.

The interventions to be scaled were a selection of those implemented in the research project and are described comparing research and scaling projects (Table 2). They included long-lasting insecticidal-nets (LLIN) on doors and windows (deployed as curtains in Colombia and permanently affixed as window and door screens in Mexico) as well as targeted interventions in the productive water container types (i.e. in container types which produce more than 70% of *Aedes* pupae. In Brazil and Uruguay community directed waste management (to eliminate small discarded potential breeding sites) and covering large containers with plastic lids (Brazil and Uruguay) or LLIN materials (Colombia) or using a biolarvicide (Mexico). Main outcomes were: the significant reduction of vector densities [15,16,19,20] people’s satisfaction with the intervention (determined through household surveys and focus group discussions; and acceptable costs (estimated through documentation of all direct costs arising during the intervention [21].

The interventions to be scaled up (from May 2015 until now) at city level to a much larger number of households (Table 2) were taken up and largely (Colombia, Mexico,

Table 1. Description of the study areas.

Country	Characteristics of the city included in the study
Brazil	<p>The city of Belo Horizonte (2,375,151 inhabitants), capital of the state of Minas Gerais, is located at 735 km from Brasília, the capital of Brazil. Belo Horizonte has an annual average temperature of 20.5 °C and mean annual precipitation of 1430 mm. Two seasons can be clearly distinguished: a rainy season, in March–October (with most of the rainfall from June–October) and a dry season from April to September.</p> <p>The city of Goiânia (1,302,001 inhabitants), the state capital of Goiás is located at 243 km from Brasília, the capital of Brazil. Goiânia has an annual average temperature of 23.1 °C and mean annual precipitation of 1414 mm. Two seasons can be clearly distinguished: a rainy season, in November to March (with most of the rainfall from June–October) and a dry season from April to September.</p> <p>The two cities have the <i>Aedes aegypti</i> vector in their territories as well as the historical transmission of the four dengue serotypes. Both cities have recently experienced chikungunya and Zika epidemics. In Belo Horizonte the total number of dengue cases were for the preceding years (2014–2016) 228,470 from which 173,939 were confirmed. In 2016, 43 confirmed cases of chikungunya were reported and 1534 of Zika from which 550 cases were confirmed. In Goiânia between 2014 and 2016, 170,733 dengue cases were reported, 157 of chikungunya. For Zika between 2015 and 2016, 8965 cases were reported and 682 confirmed.</p>
Colombia	<p>The city of Girardot (103,893 inhabitants who live in approximately 21,000 households) is located at 120 km from Bogotá, the capital of Colombia. It has an annual average temperature of 33.3 °C, relative humidity of 66.38%, mean annual precipitation of 1220 mm. It is a municipality that presents an eco-epidemiological and social niche propitious for a sustained transmission of dengue and other recently introduced <i>Aedes</i>-borne diseases like chikungunya and Zika. It is a touristic area with a floating population that triples during the vacations. Two seasons can be clearly distinguished: a rainy season, in May to November and a dry season from December to April. The total number of reported cases were for the preceding years (2014–2016) were 1584 dengue cases, 9442 chikungunya cases and 1680 Zika cases (2015–2016).</p>
Mexico	<p>The city of Merida (789,279 inhabitants who live in 272,418 households) is located in the state of Yucatan on the Peninsula of Yucatan South East Mexico. The climate in Merida is mainly warm with an annual average temperature of 26°–27 °C (36 °C max–18 °C min). Two seasons can be clearly distinguished: a rainy season, in June to November (with most of the rainfall from June–October) and a dry season from December to May. The rainy season is considered the dengue risk season and marks the starting point for vector control activities. Yucatan has shown important dengue transmission levels over the past 30 years. The total number of reported cases were for the preceding years (2014–2016) were 1247 dengue cases, 505 chikungunya cases (2015–2016) and 453 Zika cases (2016).</p>
Uruguay	<p>The city of Salto, located in the north-western part of Uruguay (31°23'S, 57°58'W) on the border with Argentina with 105,000 inhabitants and 33,000 houses. Uruguay is located at the southern border of <i>Aedes aegypti</i> distribution on the South American subcontinent. The first cases of autochthonous dengue were reported in February 2016; until this moment the reported dengue cases in the country were all imported from surrounding countries. One of the cities at higher risk of local dengue transmission is Salto with heavy traffic from dengue endemic areas (Argentina, Paraguay, Brazil and Bolivia). Recently the local transmission of dengue has been confirmed. Two seasons can be distinguished: cold season, from May to November, and hot season from December to April when virus transmission can take place.</p>

Uruguay) or exclusively (Brazil) conducted and financed by the governmental and/or private sector. The role of the research teams was the monitoring and analysis of the scaling-up process and the impact evaluation using mainly 'reduction of disease incidence' as the main outcome measure (see 'scaling experience' in Table 2). The proposed overall objective was to identify cost-effective and feasible procedures for substantially improving the process and impact of vector control interventions within national programmes in order to reduce the incidence of *Aedes aegypti* transmitted viral diseases (in the first place dengue, later on also Zika and chikungunya). The paper presented here is not dealing with the impact evaluation but with the scaling process as compared to the original research projects (Cluster Randomized Trials).

Design study of the implementation research

In each site, two to four large areas with similar socio-economic and entomological characteristics were selected and then randomised into intervention or control areas according to a quasi-experimental design. The impact of interventions is being quantified in the ongoing study comparing treatment vs. control groups regarding incidence of dengue, chikungunya and Zika morbidity/mortality, as well as vector densities (pupae per person, house index, Breteau index, adult mosquitoes inside the houses, ovitrapping). The number of reported cases (probable and confirmed cases and deaths) and available entomological historical indicators have been identified in the intervention areas and control areas during

the preceding 3 years based on the routine surveillance system.

Prospects and limiting factors of scaling up vector interventions

Studies on 'lessons learned from scaling-up experiences' are reported worldwide using quantitative and qualitative methods. Interviews, focus group, workshops, desk review documents, field work, monitoring and supervisory database are methods used to report scaling up progress [22–26].

Likewise, our analysis applied qualitative methods to understand the facilitating and limiting factors of scaling the vector control interventions. Three annual meetings of all principal investigators and their assistants were organized to ensure the consistency of data collection procedures and analysis. Data recollected from field diaries (which described the weekly activities), minutes of team meetings (every week or fortnight) and of monthly intersectoral meetings, in-depth interviews with leaders at different levels (MoH, State level, civil society; on average 15 interviews per site) was reviewed and analysed. Interview partners were purposively chosen according to their current or potential role in vector management (i.e. current vector control staff at all levels and potential contributors to vector control such as community leaders, school teachers, local businesses, waste collectors and others).

Analysis categories were defined based on: (a) scaling up lesson learned literature review [13,27,28] and

Table 2. Aedesegypti control interventions in the research project (cluster randomized trials (CRT), and the scaling up experience per study site.

Study design	Research project (Efficacy trials)						Scaling up experience			
	Brazil	Colombia	Mexico	Uruguay	Brazil	Colombia	Mexico	Uruguay		
Study type										
CRT in 10 intervention and 10 control clusters	X	X	X	X						
Quasi experimental design with control area										
Targeted households	1000	1000	1000	1000	16 338 (Belo Horizonte) 13 796 (Goiânia)	10 000	1 000–2 000	10 000		
Study area	Fortaleza	Girardot	Acapulco	Salto	Goiania & Belo Horizonte	Girardot 4 sectors	Merida 'Juan Pablo II'			
Intervention components										
Involvement of communities	X	X	X	X	X	X	X	X	X	
Involvement of vector control staff	X		X		X		X		X	
Intersectoral involvement	X	X	X		X	X			X	
Covering productive containers (plastic lids or ITN nets in aluminium frame)					X					
Removal of small discarded containers	X			X	X				X	(plastic bags for removal distributed)
ITN screens permanently installed on windows and doors		X	X		X		X			
% of coverage of large water containers	X	X								
% removal of disarded containers	X									
Increased community involvement/collabor. of control staff & commun.	X	X			X		X		X	
Improved intersectoral involvement	X				X		X		X	
Significant reduction of vector indexes	X	X	X	X	X	X	X	X	X	
% coverage of houses with curtains/screens		X	X		X	X	X	X	X	
% of acceptance	X	X	X	X	X	X	X	X	X	
Reduction of dengue, chikungunya and zika incidence					X		X		X	
Costs (incremental costs for control services)	X	X		X		X	X	X	X	local dengue transmission starting

(b) ExpandNet WHO framework adaptation of two of the principal elements of the frame work, user organization and environment. User organization is defined as institutions or organizations that adopt or implement the innovation on a large scale. It refers to active participants connected with the resource team, linked to building capacity, resources, staffing, technical competency, management and administration, organizational culture and leadership [13]. Environment is understood as the conditions that affect the prospects for scaling up, taking into account policy setting, political and sociocultural context [14].

Five levels were defined in our study:

- (1) *Political level*: Financial, human resources and/or administrative support provided by MoH or other sectors.
- (2) *Vector control level*: Support by vector control services and staff.
- (3) *Administrative level*: Regulations for involving industry in the process; management issues Project activities definition, field team and local enterprises
- (4) *Supply*: Availability and acquisition of materials.
- (5) *Acceptance*: Acceptance by the community and by vector control staff.

The analysis was conducted by the research team of the four cities under the coordination of the TDR-WHO manager in Geneva. Biannual meetings of the four teams complemented the ongoing electronic interaction among Principal Investigators.

Results

The prospects and limitations of scaling up the vector control interventions will be presented in the following sections; they are summarized in Table 3.

Policy level: political approval and support

Collaboration with institutions at national, state and municipal levels during the scaling process had to deal with different kinds of challenges experienced in the participating countries:

The *Brazilian* Ministry of Health (MoH) when reviewing the research findings of the four countries (Table 2) was particularly impressed by the significant effect of window/door screens on vector densities shown in Mexico [15,16]. Therefore, the dengue programme allocated 1.2 Million USD as a start-up capital for the scaling initiative in two major cities (Belo Horizonte and Goiania) and to support actively the intervention. In addition, the cooperation and political support at municipal level was excellent providing the necessary basis for the scaling-up process. The political will, however, was hampered by administrative difficulties (see below).

In *Colombia*, there were local and state elections in October 2015. However, a multisectoral committee was established with the participation of the current municipal administration as well as of civil society representatives, universities and private sector institutions. In spite of the change of local authorities after the elections, a transition process was initiated that required efforts to explain to the new Mayor and his team the purpose and objectives of the scaling-up programme. Understanding and practical collaboration was fast so that the programme could be continued. The National level, represented at the committee by the MoH, ratified the donation of a large quantity of insecticide treated materials for water container covers (the predominant productive containers in the city) at an estimated cost of 12,000 USD.

In *Mexico*, strong political approval and collaboration both at national and State levels were present during the development of the research project in Acapulco. There was no active participation of the national Vector Borne Disease Control Program, but the local MoH provided facilities and staff. The intervention was later on replicated in Merida/Yucatan State with the co-funding by the Mexican MoH and Education Research Support (CONACYT), and the support and the collaboration of local authorities and local enterprises. The scaling project was approved by the Mexican MoH but due to changes of the senior management after elections at national, state and municipality levels new agreements had to be worked out which delayed the start of the programme. The government of Yucatan, through the Ministry of Research, Innovation and Higher Education is currently supportive and actively looking for funds and administrative support.

In *Uruguay* electoral processes at national (October and November 2014) and local (May 2015) level created uncertainty in terms of financial support of the scaling-up initiative but the elected authorities (the same political party at national level and different political party at local level) ratified support particularly through staff costs.

Vector control level: staff support and coordinated actions

Vector control interventions in Latin American countries are delivered by national and local vector control programs. These are structured programmes with fixed methodologies and practices; there is often limited funding and lack of commitment. Therefore the introduction of new tools or of novel entomological survey methodologies often encounter resistance among control staff working with the vector control staff is based on decisions by the authorities as well as willingness and ability to collaborate in a new programme.

In *Belo Horizonte/Brazil* the year 2015 has been marked by a difficult political-administrative situation with three

Table 3. Summary of favouring and limiting factors when scaling up vector control interventions in different contexts.

Country	Research project (Efficacy trials)							Scaling up experience		
	Political	Vector control staff	Management and administration	Resources	Acceptance	Political	Vector control staff	Management and administration	Resources	Acceptance
Brazil	Political approval but no direct support of project activities	Direct support by vector control services; financial incentives & re-training for control staff. Intervention paralyzed by strikes	Import of materials for research purposes was not a problem. Contact of researchers with industry facilitated purchase of goods. Continuous monitoring ensured satisfactory results	Local companies were contracted by researchers. Prices were negotiated.	Acceptance and recognition of the research team by the community	Political support from national and municipal level	Intervention done by control staff. Repeated strikes delayed activities. Limited staff training & supervision	Anonymous bidding process (acc. to Gvt. rules) did not reach smaller companies	Difficult import rules complicated bidding process	Positive feelings about the measure. Opinion influenced by control staff
Colombia	Political approval at municipal level, but no yet direct participation of the city administration in project activities	Vector control staff participated in training activities. Staff supervision by project team was not feasible	External financial support. Import of materials done by research team; costs increased (exchange rate). Lack of field staff due to weak support of municipal authorities. Field activities were exclusively coordinated/performed by researchers	Local companies with poor manufacturing practices. Continuous monitoring is required. Local companies were hired and supplies were purchased by the research team	Frequent household visits and use of local tailors increased acceptance and recognition of the research team by the community	Political support from all levels; Intersectorial committee created involving city administration, schools, universities hospitals, chamber of commerce, MoH, Hotels	Collaboration of vector control staff dependent on the municipal authority	Poor performance of vector control staff; limited administrative commitment of municipal authorities	Slow installation due to scale of project. LLINs provided by MoH or purchased with external funds. Contracting local companies presented legal problems	Acceptance relied on researchers representing a well known national health institution
México	Strong political approval and collaboration both at National and State level during the development of the research project	No participation of the national control programme but limited involvement of local control staff	Interventions organized by the research project, external financial support. Most activities performed by the research team. Continuous monitoring was important	Necessary materials were donated. Local companies were hired by the research institution	Remarkable acceptance of the intervention & researchers by the community	The intervention was scaled up 'horizontally' in Merida with funds from different sources	State government reluctant to support 'research' due to disease outbreaks. Vector control staff busy with the containment	Limited administrative commitments for supporting the scaling-up initiative due to lack of resources & facilities in the Governmental sector. Previous commitments blocked the shift of resources	Donation of LLINs not feasible in the government sector. Contracting local companies difficult due to legal issues	Acceptance relied on the research team. Promotional activities underway
Uruguay	Political approval but no direct collaboration in project activities	Support by vector control services; control staff worked jointly with research staff; financial incentives for control staff. Staff training and supervision is feasible	University administered external funds. Daily availability of funds for research was not a problem	Material availability was not a problem	Very good acceptance of the project team by the community	Political support from national (MoH) and municipal level favoured by friendly relationship	Control staff actively involved in intervention activities. Training & supervision of staff was optimal	Fast administrative procedures for purchasing material from local companies. Slow MoH process to provide field staff	Scaling up costs were not higher than routine actions	Excellent acceptance by the community. Joint planning between public health institutions, project staff and community organizations was achieved

strikes of vector control staff and partially other health workers for a total of about 12 weeks. This and the premature death of the local manager of the scaling initiative delayed all planned activities considerably. In Goiânia and Belo Horizonte when vector control staff was trained in two occasions on dissemination of information about the proposed interventions, improved partnership with the community and how to support the installation of window screens they showed interest in the approach and high commitment.

In *Mexico* during the efficacy trials local vector control staff participated in all activities within the research project and the positive results were well appreciated by the MoH at national, state and municipal level as well as by the vector control staff, but dengue, chikungunya and now Zika outbreaks had a direct impact on participation. In 2015 a dengue/chikungunya outbreak affected the country. Emergency vector control operations using traditional insecticide based control strategies were a priority. This is why local governments both in Guerrero and Yucatan State were reluctant to support with vector control staff the scaling-up initiative which was at the beginning perceived to be 'research'. Furthermore, due to the political changes mentioned above, vector control staff was not anymore allowed to cooperate with scaling-up activities.

In *Colombia* vector control staff participation within the research project was possible at early stages and depended on the decision of the local administration. Once the scaling initiative had started a new local administration came into place, which –in the Colombian decentralized administrative system – is responsible for appointing vector control staff and organizing the activities. While the new administration settled, during the first 2 months of the scaling process it was not possible to work with sufficiently qualified staff in the scaling up activity so that the research team had to step in and help with vector surveillance. Meetings with the new state and municipal administration helped to socialize the project and consolidate in a joint effort for the scaling process.

In *Uruguay* it was possible to coordinate actions between the MoH and the municipality. However, intervention activities were affected by financial and logistical difficulties at municipal level (municipal trucks in bad shape). The project team was forced to hire additional trucks for waste removal.

Administrative level: working with local enterprises

In all four countries there was during the scaling up initiative a mis-match between the timing of the interventions and getting the required field staff and supplies. This was enhanced by the chikungunya outbreak, and more recently, the Zika virus disease outbreak.

In *Brazil/Belo Horizonte* the intervention faced significant operational challenges. The Mayor's Office had decided in February 2016 only, to start activities after having had clear perspective of the timeframe of the installation of insecticide treated curtains. The city of Belo Horizonte decided to install wooden screens because they are more affordable – about 60 Real (15 USD for each house) –. Up to now, nets were placed in 100 houses. Similarly, in Goiânia the research was facing different administrative problems. The greatest challenge was identifying local enterprises to produce and install tailor-made window screens; the bidding process took nearly one year and resulted in selecting the wrong company and enterprises not accustomed to the bidding process (see Colombia experience below). The costs of the installed frames were much higher than anticipated: instead of the expected 40 Reals (10 USD) per linear meter, the price was 80 Reals (20 USD). Given this difficulty, only a reduced number of households could be protected by window screens: 3500 households instead of the originally targeted 12,000 homes. Long-lasting insecticide treated nets (Duranet TM) for window and door screens were provided by the Goiânia municipality and by the MoH through the Panamerican Health Organization (PAHO). During the first six months, nets 4006.23 square meters of nets were installed in the intervention areas. The Municipality set up a team to perform the window measurement in all houses that had been reported by the company to receive frames and screens. A considerable difference between the services reported by the company and really conducted was detected so that an audit process was initiated. At the same time a second bidding process was started which currently is not yet completed.

In Belo Horizonte, screens were installed in 100 houses of the intervention areas. Following this positive experience, Belo Horizonte Municipality decided in March 2016 to install treated nets at windows and doors of households with pregnant women.

In *Colombia* the administration of the scaling up process was largely done by the research team with financial support of local enterprises. Most of the field activities were exclusively coordinated and performed by the research team until the new municipal administration was operational. The building of the interventions (frames with LLIN for the low tanks) is a mechanism of income generation for small enterprises of the community. The research team has also managed this, and difficulties have been found in the response of the local enterprises to comply with the required products.

In *Mexico* (as in Colombia) the administration of the replication/scaling up activities was done by the project team and gradually with a more active involvement of other partners.

In *Uruguay* the Universidad de la República administered the research funding by WHO–TDR that allowed to purchase the materials needed for the activity (just as in

the preceding research project) but obtained from the MoH the permission to work with local field staff.

For all four countries there was in the scaling up initiative no match between the timing of getting the required field staff and requirements of the intervention activities. This was at a later stage enhanced by the chikungunya, and more recently, the zika virus disease outbreak.

Supply level: material acquisition

At the supply level, the constraints refer to the acquisition of materials (screens, aluminium frames, window curtains, plastic bags for collection of small discarded containers).

In *Brazil* this was an obvious problem as the public sector has defined rules for purchasing materials. Particularly the acquisition of insecticidal materials is a sensitive issue and the Department of Communicable Disease Surveillance (*Departamento de Vigilância das Doenças Transmissíveis*) at the MoH had to issue a legal justification, why certain materials are required. Furthermore, excessive prices may be prohibitive or make the intervention less cost-effective.

In *Colombia*, and in *Mexico* the MoH donated LLIN suitable for scaling up the cover of water tanks. Additional materials had to be acquired from international companies by the research team using funds from development and research institutions. Some of the local companies that elaborated and installed the frames and nets for covering water tanks had poor manufacturing practices. Local companies were essential to endorse community participation in the installation process but issues with prices, deadlines, acquisition of supplies and monitoring operational and logistic plans were always present. Finally, an external company from the capital Bogota had to be involved, which showed satisfactory performance. However, continuous monitoring by the research team was and is required.

Uruguay had no problems with the acquisition of supplies, as these were available on the local market or in local companies (mainly plastic bags for rubbish collection and plastic sheets to be used as water container covers). The costs could be shared between the research team and the MoH and the bulk purchase of materials lowered the price considerably.

Acceptance level

The scaling-up initiative is not just the curtain or the screen or the plastic bag, it has to do with people and how they react to novel interventions. A community leader in Goiania expressed it in the following way: *(It's so hard to change habits. Working with this for 15 years and nothing changes. So I don't see a solution to dengue)*

In *Brazil* it was clear that acceptance relies on peoples' perceptions but also on opinions by vector control staff.

In Belo Horizonte control staff said: *(I think the greatest difficulty is the issue of the relationship with the residents).*

In Goiania, personnel working in public buildings, who were the first to benefit from the window screens, expressed their positive feelings about the measure. Vector control staff, however, was aware of the high levels of vector resistance to pyrethroid insecticides and expressed their view that probably the physical barrier was the one which protected people from being bitten.

In *Colombia* urban community acceptance of the intervention continued to rely mainly on the research team representing a well-known national health research institution. Through different strategies, the involvement of local stakeholders enhanced the acceptance and demand of the interventions. The establishment of an intersectoral committee was one of the most important strategies not only for acceptance but also for a clear leadership towards sustainability.

In *Mexico* the community acceptance was usually high; people acknowledged to see dead insects under the window screens in the morning and perceived less insect biting. Those who did not accept the window screens were usually un-informed or suspicious that in the end they had to pay for the screens. MoH staff including vector control personnel has also a positive view of the intervention in Merida (Steinmeyer, personal communication).

In *Uruguay* the response of local neighbourhood committees, schools, children associations, polyclinics and others for taking part in the scaling-up activities was very positive. Neighbours agreed to receive the bag and returned it the next couple of days filled with discarded small containers.

Discussion

The examples from the four countries for the attempt of scaling new dengue vector control methods and strategies show the range from a real-time scaling initiative by the national dengue control programme (*Brazil*) to the 'quasi scaling up project' maintaining many elements typical for research projects (*Mexico*) with the initiatives in *Colombia* and *Uruguay* being in-between. The different scenarios represent examples for the 'vertical approach' (conducted and taken up by the governmental sector) and the 'horizontal approach' (replication of a successful intervention at scale; see introduction). Important lessons learned in this initiative are supported by other scaling up experiences worldwide. Political will to support the initiative is crucial (in our study in *Brazil* and *Uruguay*) as Yamey et al. [12] had identified in relation to the socio-political context. Other external factors may override high level decisions. Examples in our studies are: (a) Change of government (i.e. of decision makers) with a change of opinions and the neglect of previous agreements; sometimes unclear decision-making power in a

decentralised administrative system (where the national, state/departmental and municipal level compete); (b) Advent of major epidemics (chikungunya, Zika) moving all resources into another direction; (c) Administrative constraints (long term budget plans do not allow short or medium term shifts); (d) Inflexible rules in the public administration which impede the timely acquisition of materials and implementation with the necessary human resources; (e) Inertia of public health workers resisting change; (f) Low quality machines (e.g. municipal trucks in Uruguay) or low quality materials or un-experienced industrial partners (e.g. for the installation of screens and water container covers in Brazil and Colombia); (g) Strikes by vector control staff make timely implementation of measures difficult (see Brazilian example). These implementation barriers do not exist or are of minor importance in research projects, where a lengthy bidding process can be avoided, donations from industry can be obtained, payment of incentives to control staff can be done and quality assurance is not a major issue.

Coordination with different sectors is in our experience one of the key elements for scaling up a project see also [29]. Extended interventions require input and leadership from multiple sectors, particularly from Ministries of Health (MoH), Environment and Social Protection [13,28]. Particularly the MoH has to ensure political commitment [14,30] and support the process with staff and financial resources. This was also shown by Magesa et al. [31] in a national scaling up project of insecticide treated nets for malaria control in Tanzania. Scaling up generally involves a partnership of organizations working on service delivery, financing and stewardship [30,32,33] as well as of community leaders [34,35]. Also the adaptation to the social context has been shown to be a crucial element for the scaling up process [11,13,36]. Engaging community members as staff or local suppliers can reduce costs and strengthen ownership (e.g. in Uruguay and Colombia).

Particularly interventions in private houses require the consent and acceptance of the local community. This may be a straightforward process in a small scale research project as experienced in our preceding research phase (see Table 2). However, when large population groups from different socio-economic strata have to be reached, different communication strategies may be required in order to avoid misunderstandings or lack of information (see Mexican example). Unfortunately vector control staff who could be important communicators when visiting households for larval surveys and vector control, are rarely trained on how to establish bonds with families as well as on modern communication technologies [6].

Conclusion

It can be concluded that scaling up novel vector control interventions is a complex process. Being the emerging arbovirus diseases (dengue, chikungunya, Zika, yellow

fever) a new public health threat of international concern, the international community should be prepared to help countries in scaling up vector control tools and strategies for reversing the trend [37].

Authors contributions

AC, AK and JQ drafted the manuscript. JQ and AK edited the manuscript. TGB, AC, AK, JQ, GC, PMS, CB, EA and JS advised on and reviewed data, and contributed to discussion. TGB performed a narrative literature review regarding types and processes of scaling up interventions. All authors read and approved the final manuscript.

Availability of data and materials

Data sharing not applicable to this article as no datasets were generated during the current study. The manuscript only contains a descriptive perspective of the research teams regarding scaling up process of the interventions implemented.

Consent for publication

Not applicable.

Declarations

Ethics approval and consent to participate

The research accompanying the interventions was reviewed and cleared by national Research Ethics Review boards of all countries as well as the Research Ethics Review Committee (ERC) of the World Health Organization (WHO). Within the interventions written consent was obtained from the individuals who agreed to participate in the scaling up of the interventions.

Acknowledgements

We thank the national and local governments in Brazil, Colombia, Mexico and Uruguay for the support of the interventions and scaling up initiative.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was financially supported by the UNICEF/UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) and International Development Research Center (IDRC) [grant number HQTDR1409927]; In Mexico, the studies additionally received financial support by el Consejo Nacional de Ciencia y Tecnología (CONACYT) through the Projects 'Control integrado de Ae. aegypti con estrategias y herramientas innovadoras en la zona de alto riesgo para la transmisión del

dengue en Guerrero México' y 'Casas y escuelas a prueba de *Aedes aegypti* para maximizar el control y la prevención del dengue en áreas de riesgo en Yucatán'. In Colombia, the study received additional support of the International Development Research Center (IDRC) through the project 'Intersectoral Municipal Leadership for Health' and by the Departamento de Ciencia, Tecnología e Innovación Colciencias (CTel) and through the project 'Enfoque Ecobiosocial para el diseño e implementación de una estrategia sostenible para el control del vector de dengue en Girardot, Fase 3. Viabilidad y costo efectividad de una intervención innovadora para el control del vector de dengue' [project number 622172553374].

ORCID

Juliana Quintero <http://orcid.org/0000-0003-3005-4184>
 Tatiana García-Betancourt <http://orcid.org/0000-0002-1567-5030>
 Andrea Caprara <http://orcid.org/0000-0002-8725-4710>
 Giovanini Coelho <http://orcid.org/0000-0002-7804-3073>
 Felipe Dzul-Manzanilla <http://orcid.org/0000-0002-2085-9141>
 Gabriel Carrasquilla <http://orcid.org/0000-0002-9449-4931>
 Eduardo Alfonso-Sierra <http://orcid.org/0000-0001-6430-5135>
 Johannes Sommerfeld <http://orcid.org/0000-0003-1051-8412>
 Axel Kroeger <http://orcid.org/0000-0001-8438-2904>

References

- [1] World Health Organization. Global strategy for dengue prevention and control 2012–2020. Geneva, Switzerland: World Health Organization Press; 2012. Available from: http://apps.who.int/iris/bitstream/10665/75303/1/9789241504034_eng.pdf
- [2] Bowman LR, Donegan S, McCall PJ. Is dengue vector control deficient in effectiveness or evidence?: systematic review and meta-analysis. *PLoS Negl Trop Dis*. 2016;10(3):1–24.3.
- [3] Achee NL, Gould F, Perkins TA, et al. A critical assessment of vector control for dengue prevention. *PLoS Negl Trop Dis*. 2015;9(5):1–19.
- [4] World Health Organization. Handbook for integrated vector management. *Outlooks Pest Manag* [Internet]. 2013;24(3):142–143. Available from: <https://openurl.ingenta.com/content/xref?genre=article&issn=1743-1026&volume=24&issue=3&page=142>
- [5] Gómez-Dantés H, San Martín JL, Danis-Lozano R, et al. Grupo de dengue. *Salud Publica Mex. 2011;53(supl 3):S349–S357.
- [6] Horstick O, Runge-Ranzinger S, Nathan MB, et al. Dengue vector-control services: how do they work? a systematic literature review and country case studies. *Trans R Soc Trop Med Hyg* [Internet]. 2010 Jun;104(6):379–386. [cited 2012 Jul 19]. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/20400169>
- [7] Focks DA, Alexander N. Multicountry study of *Aedes aegypti* pupal productivity survey methodology. *Trop Med* [Internet]. 2006;31:56. Available from: https://www.researchgate.net/profile/Neal_Alexander/publication/268293666_Multicountry_study_of_Aedes_aegypti_pupal_productivity_survey_methodology_Findings_and_recommendations_/links/54c8ead0cf289f0ced11def.pdfhttps://www.searo.who.int/LinkFiles/Dengue_
- [8] Tun-Lin W, Lenhart A, Nam VS, et al. Reducing costs and operational constraints of dengue vector control by targeting productive breeding places: a multi-country non-inferiority cluster randomized trial. *Trop Med Int Heal* [Internet]. 2009 Jul 25;14(9):1143–1153. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/19624476>
- [9] Sommerfeld J, Kroeger A. Innovative community-based vector control interventions for improved dengue and Chagas disease prevention in Latin America: introduction to the special issue. *Trans R Soc Trop Med Hyg*. 2014;109(2):85–88.
- [10] World Health Organization. Scaling up health service delivery: from pilot innovations to policies and programmes/edited by Ruth Simmons, Peter Fajans, and Laura Ghiron [Internet]. 2007. Available from: http://www.who.int/immunization/hpv/deliver/scalingup_health_service_delivery_who_2007.pdf
- [11] Yamey G. Scaling up global health interventions: a proposed framework for success. *PLoS Med* [Internet]. 2011 Jun;8(6):e1001049. [cited 2014 May 17]. Available from: <https://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3125181&tool=pmcentrez&rendertype=abstract>
- [12] Mangham LJ, Hanson K. Scaling up in international health: what are the key issues? *Health Policy Plan* [Internet]. 2010 Mar;25(2):85–96. [cited 2014 May 15]. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/20071454>
- [13] ExpandNet WHO. Practical guidance for scaling up health service innovations. Geneva: WHO; 2009.
- [14] World Health Organization. Beginning with the end in mind: planning pilot projects and other programmatic research for successful scaling up. Geneva, Switzerland: World Health Organization; 2011. Available from: http://apps.who.int/iris/bitstream/10665/44708/1/9789241502320_eng.pdf
- [15] Manrique-Saide P, Che-Mendoza A, Barrera-Perez M, et al. Use of insecticide-treated house screens to reduce infestations of dengue virus vectors, Mexico. *Emerg Infect Dis* [Internet]. 2015;21(2):308–311.
- [16] Che-Mendoza A, Guillermo-May G, Herrera-Bojórquez J, et al. Long-lasting insecticide-treated house screens and targeted treatment of productive breeding-sites for dengue vector control in Acapulco, Mexico. *Trans R Soc Trop Med Hyg*. 2014;109(2):106–115.
- [17] Morales PAK. PROYECTO de Norma Oficial Mexicana PROY-NOM-032-SSA2-2014, Para la vigilancia epidemiológica, prevención y control de enfermedades transmitidas por vector. D Viernes 22 agosto 2014 Prim sección [Internet]. 2014;1–47. Available from: https://www.americanbanker.com/issues/179_124/which-city-is-the-next-big-fintech-hub-new-york-stakes-its-claim-1068345-1.html<https://www.ncbi.nlm.nih.gov/pubmed/15003161><https://cid.oxfordjournals.org/lookup/doi/10.1093/cid/cir991><https://www.scielo.cl/pd>
- [18] Basso C, da Rosa EG, Romero S, et al. Improved dengue fever prevention through innovative intervention methods in the city of Salto, Uruguay. *Trans R Soc Trop Med Hyg*. 2014;109(2):134–142.
- [19] Caprara A, Lima JWDO, Peixoto ACR, et al. Entomological impact and social participation in dengue control: a cluster randomized trial in Fortaleza, Brazil. *Trans R Soc Trop Med Hyg*. 2015;109(2):99–105.
- [20] Quintero J, García-Betancourt T, Cortés S, et al. Effectiveness and feasibility of long-lasting insecticide-treated curtains and water container covers for dengue vector control in Colombia: a cluster randomised trial. *Trans R Soc Trop Med Hyg*. 2014;109(2):116–125.

- [21] Alfonso-Sierra E, Basso C, Beltran-Ayala E, et al. Innovative dengue vector control interventions in Latin America: what do they cost? *Pathog Glob Health* [Internet]. 2016;7724(April):1–11. Available from: <https://doi.org/10.1080/20477724.2016.1142057>
- [22] Ghiron L, Shilling L, Kabiswa C, et al. Beginning with sustainable scale up in mind: initial results from a population, health and environment project in East Africa. *Reprod Health Matters* [Internet]. 2014;22(43):84–92. Available from: [https://doi.org/10.1016/S0968-8080\(14\)43761-3](https://doi.org/10.1016/S0968-8080(14)43761-3)
- [23] Yamey G. What are the barriers to scaling up health interventions in low and middle income countries? a qualitative study of academic leaders in implementation science. *Global Health* [Internet]. 2012;8(1):11. Available from: <https://globalizationandhealth.biomedcentral.com/articles/10.1186/1744-8603-8-11>
- [24] Corbin JH, Mittelmark MB, Lie GT. Scaling-up and rooting-down: a case study of North-South partnerships for health from Tanzania. *Glob Health Act*. 2012;5(1):18369.
- [25] Keyonzo N, Nyachae P, Kagwe P, et al. From project to program: Tupange's experience with scaling up family planning interventions in Urban Kenya. *Reprod Health Matters* [Internet]. 2015;23(45):103–113. Available from: <https://doi.org/10.1016/j.rhm.2015.06.010>
- [26] George A, Menotti EP, Rivera D, et al. Community case management in Nicaragua: lessons in fostering adoption and expanding implementation. *Health Policy Plan*. 2011;26(4):327–337.
- [27] Nsutebu EF, Walley JD, Mataka E, et al. Scaling-up HIV/AIDS and TB home-based care: lessons from Zambia. *Health Policy Plan* [Internet]. 2001 Sep;16(3):240–247. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/11527864>
- [28] FischerWalkerCL, FribergIK, BinkinN, et al. Scaling up diarrhea prevention and treatment interventions: a lives saved tool analysis. *PLoS Med* [Internet]. 2011 Mar;8(3):e1000428. [cited 2014 May 6]. Available from: <https://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3062532&tool=pmcentrez&rendertype=abstract>
- [29] Binswanger HP. Scaling up HIV/AIDS programs to national coverage. *Science* (80-) [Internet]. 2000 Jun 23;288(5474):2173–2176. [cited 2014 May 17]. Available from: <https://www.sciencemag.org/cgi/doi/10.1126/science.288.5474.2173>
- [30] Fitzgerald J, Dahl-Regis M, Gomez P, et al. A multidisciplinary approach to scaling up HIV/AIDS treatment and care: the experience of the Bahamas. *Pan Am J Public Heal* [Internet]. 2005 Jan;17(1):66–72. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/15720883>
- [31] Magesa SM, Lengeler C, deSavigny D, et al. Creating an 'enabling environment' for taking insecticide treated nets to national scale: the Tanzanian experience. *Malar J* [Internet]. 2005 Jan;4:34. [cited 2014 May 17]. Available from: <https://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1190210&tool=pmcentrez&rendertype=abstract>
- [32] Pevzner ES, Vandebriel G, Lowrance DW, et al. Evaluation of the rapid scale-up of collaborative TB/HIV activities in TB facilities in Rwanda, 2005–2009. *BMC Public Health* [Internet]. 2011 Jan;11(1):1009. [cited 2014 May 17]. Available from: <https://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3146874&tool=pmcentrez&rendertype=abstract>
- [33] Tambo E, Adedeji AA, Huang F, et al. Scaling up impact of malaria control programmes: a tale of events in Sub-Saharan Africa and People's Republic of China. *Infect Dis poverty* [Internet]. 2012;1(1):7. Available from: <https://www.scopus.com/inward/record.url?eid=2-s2.0-84885376260&partnerID=tZotx3y1>
- [34] Chambers R, editor. Going to scale with community-led total sanitation: reflections on experience, issues and ways forward. Brighton: Institute of Development Studies; 2009.
- [35] Anchalia MM, D'Ambruso L. Seeking solutions: scaling-up audit as a quality improvement tool for infection control in Gujarat, India. *Int J Qual Heal Care* [Internet]. 2011 Aug;23(4):464–470. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/21486857>
- [36] Simmons R, Shiffman J. Scaling up health service innovations: a framework for action. Scaling up health service delivery: from pilot innovations to policies and programmes [Internet]. 2007:1–30. Available from: https://expandnet.net/PDFs/Scaling-Up_Health_Service_Delivery-WHO-ExpandNet.pdf
- [37] WHO Regional Office for South-East-Asia, editor. Comprehensive guidelines for prevention and control of dengue and dengue haemorrhagic fever. 1st ed. New Delhi: World Health Organization; 2012.