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Emerging arbovirosis (Dengue, Chikungunya, Zika) in the Southeastern Mexico: influence of social and environmental determinants on knowledge and practices. A mixed method study.

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Abstract

Background: The incidence and geographical distribution of arboviruses is constantly increasing. The epidemiological patterns of the proliferation of viruses and their vectors (*Aedes aegypti* and *Aedes albopictus*) are associated with socio-environmental determinants, and are closely related to human habits, especially at the household level. The aim of this work is to analyze the influence of socio-environmental determinants on the knowledge and practices related to arboviruses and their transmission, among the residents of three communities on the southern border of Mexico.

Methodology: Between June 2017 and August 2018, our investigation covered a set of 149 households from three communities of Tapachula (Chiapas) and Villahermosa (Tabasco). We first conducted household surveys about knowledge and practices on arbovirosis. Then, we carried out direct observations of risk factors for vector proliferation at the domestic level, before and after exposing a part of the population to a cycle of community engagement prevention activities. Through semi-structured interviews, we also focused on the detection of environmental risk situations for vector breeding at the community level.

Key results: We found that most dwellings had an adequate knowledge about the origin and transmission of arboviruses, but only a minority of them also implemented appropriate practices. Higher education levels were associated with better prevention scores. The observations made after the cycle of community activities in Chiapas revealed a decrease in the accumulation of unprotected water deposits. A higher percentage of domestic risk practices were detected in association with significant deficiencies in sanitation and water supply services. Furthermore, the perception of greater risk and difficulty in complying with preventive measures was detected among the population.

Discussion: Knowledge does not necessarily lead to adequate prevention practices. A better understanding of all these dimensions and their interactions is required. In addition to the educational level, intermediate social determinants (such as water supply and environmental sanitation) influence

45   the persistence of behaviors that are risk factors for the proliferation of arbovirosis. The achievement

46   of an effective and sustainable vector management is required to address these related aspects.

47

48   **Author summary**

49   Dengue, Chikungunya and Zika are arboviral diseases, transmitted by *Aedes* mosquitoes. As a result

50   of a continuous increase in the geographical spread and burden of disease, arbovirosis have become

51   a priority issue for global health.

52   The proliferation of viruses and their vectors are influenced by a complex interaction of

53   environmental and social determinants. Thus, the design of effective and sustainable prevention and

54   control measures requires an understanding of all these different aspects.

55   The aim of our work is to explore the effects of social and environmental factors on the knowledge

56   and practices related to Dengue, Chikungunya and Zika and their transmission, among the residents

57   of three communities on the southern border of Mexico, currently an endemic area. Our study draws

58   on the application of a program combining the implementation of new technologies for vector

59   management with a participatory and holistic multidisciplinary approach.

60   Between June 2017 and August 2018, we used different surveys and methodological approaches to

61   explore knowledge and practices on arbovirosis, as well as to identify risk factors for vector

62   proliferation. We found that intermediate social determinants (such as occasional water supply and

63   infrequent waste collections) influence the persistence of behaviors that are risk factors for the

64   proliferation of arbovirosis.

65   Public health interventions for arbovirosis prevention must be accompanied by intersectoral work that

66   includes the improvement of these related aspects, according to the multifactorial etiology of

67   arboviruses.

68

Introduction

70 Dengue (DENV), Chikungunya (CHIKV) and Zika (ZIKV) are arthropod-borne viruses (arboviruses).

71 In America, *Aedes aegypti,* is the main vector involved in its transmission. It's a tropical mosquito of

72 urban distribution, widely adapted to domestic environments, and with a worldwide distribution [1,

73 2].

74 In the context of the Region of the Americas, already endemic for DENV [3] and with high infestation

75 levels of *Aedes* [2], the recent spread of CHIKV and ZIKV (with the first cases of autochthonous

76 transmission at the end of 2013 and in the 2014, respectively) represent a threat and an important

77 challenge for public health systems in the Region of the Americas [4-6].

78 The global burden of arboviral disease, and its rapid geographical spread, represents a growing public

79 health problem and needs the formulation of effective strategies for the reduction of proliferation of

80 viruses and their vector. Therefore, it is extremely important to understand the nature and interaction

81 of the risk factors behind the emergence, reemergence and persistence of arboviral disease [1, 2, 7,

82 8].

83 The epidemiological patterns associated with the arboviral infection are the result of deep and

84 complex interactions between biological, ecological, social, cultural and economic factors.

85 Vulnerable contexts, with limited conditions of socio-economic development, weak health care

86 systems and inadequate infrastructures are most disproportionately impacted by the infection, with

87 consequences for the health and the economy that hinder the progress of the communities [7-12].

88 Human habits, especially at the domestic level, play a fundamental role in the spread of the disease,

89 due to its close relationship with domestic and peri-domestic *Aedes* larval infestation indices:

90 entomological indicator of the proliferation of the vector, and therefore, transmission risk of the

91   disease [13,14].

92   Reducing the vector population represent, currently, the only effective strategy to control arboviral

93   transmission. Since the epidemiological patterns of the arboviral disease are associated with a set of

94   social and environmental determinants, World Health Organization (WHO) strongly recommends the

95   implementation of Integrated Vector Management as a required model for the control and prevention

96   of arboviral disease [7-9,15].

97   Our study draws on the application of a Multidisciplinary and Transversal (MT) project "Desarrollo

98   de tecnología para el manejo integral de mosquitos vectores de dengue, chikungunya y Zika en

99   Guatemala y México" ("Mosquito-MT project"), a prevention pilot program combining the

100   implementation of the Sterile Insect Technique (SIT) with a participatory and holistic approach [16,

101   17]. Even if the SIT could represent an effective and sustainable alternative to traditional vector

102   control programs, its introduction should be accompanied by an integrated approach including

103   participation of local stakeholders. It has been remarked the importance of taking a community-based

104   approach in vector borne disease interventions, especially when they include the implementation of

105   new technologies for health [11, 18-21].

106   In recent years, the southern border of Mexico has been affected by repeated outbreaks and epidemics,

107   with a high impact on the health and the economy of the area. It is currently a highly endemic area

108   for the three diseases [22, 23].

109   The aim of this work is to analyze the influence of socio-environmental determinants on the

110   knowledge and practices related to ZIKV, DENV and CHIKV and their transmission, among the

111   residents of three communities on the southern border of Mexico, before and after carrying out a cycle

112   of community activities with a part of the target population of the "Mosquito-MT project."

113

114   **Methods**

5

Study setting and participants

The study was conducted between June 2017 and August 2018 at three rural villages on the southern border of Mexico, on the outskirts of two large urban centers: *Ejido* Hidalgo, *Ejido* Río Florido (near Tapachula, state of Chiapas) and *Ranchería* Guineo Segunda Sección (near Villahermosa, state of Tabasco).

According to the National Institute of Statistics and Geography, in 2010 the estimated population of Guineo Segunda Sección was 1032 inhabitants (298 dwellings), with 24.9% of the population over 15 years of age without complete elementary school. Besides, the estimated population of the Tapachula's villages was 789 inhabitants (172 dwellings) in Rio Florido and 697 inhabitants (184 dwellings) in Hidalgo. The percentage of the population over 15 years of age without complete basic studies was 29.1% in Río Florido and 36.7% in Hidalgo. We gathered the obtained data of both villages because of their proximity (3 km apart), and the similarity of their overall condition [24].

Three different surveys were planned and the sample size for each was 149 households, with a total of 643 residents (82 households in Tapachula municipality, 67 households in Villahermosa municipality) and 6 key informants (2 participants from each community). The households were chosen through simple random sampling, while the key informants were chosen through purposive sampling. The key informant respondents were recruited primarily through the local community health center and the local community organization *Asamblea ejidal* [18]. A person from the *Comisariado ejidal* (representation of the *Asamblea ejidal)* of each community accompanied us during the process of the fieldwork, to achieve better understanding and acceptance with the rest of community.

In the Tapachula's villages, two of the co-authors (AD and ALP) were conducting a community engagement plan, between November 2017 and July 2018. Through a collective and co-participative work, involving different social actors of the communities, different topics related to vectors and

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139   viruses were addressed, in order to improve capacities and informed decision-making about

140   arbovirosis management and prevention. In addition to the active participation in the *Asamblea ejidal*

141   meetings, a cycle of activities (talks, participatory workshops, community theater) for specific groups

142   (women, children, adolescents) was designed**.**

Study design

144   We conducted a mixed methods study, structured in two complementary phases. Phase I: in June

145   2017, prior to the start of the community engagement interventions, we visited 149 randomly selected

146   households. We applied one Household Survey about knowledge and practices on arbovirosis and

147   one Risk Observational Assessment about risk practices for vector proliferation at the domestic level,

148   per dwelling unit. Phase II: during July and August 2018, we re-applied the Risk Observational

149   Assessment to the same households of previous phase, after exposing a part of the population to a

150   cycle of community engagement prevention activities. We also applied a Community Background

151   Survey, focused on the detection of environmental risk situations predisposing to vector proliferation

152   at the community level.

Surveys

Household Survey

155   In 2017, through a structured, standardized and precoded questionnaire (S1.A File), we first obtained

156   information about the sociodemographic characteristics of the household residents. Then we focused

157   on basic knowledge on arbovirosis and its prevention. We first asked questions related to the origin

158   and transmission of arbovirosis i.e. "how do you think is Dengue/Zika/Chikungunya transmitted?"

159   (categorized as knowledge in the S1.A File).

160   Finally, we asked about the use of preventive measures i.e. "how do you avoid from mosquito bites?"

161   and "how do you keep mosquitoes from breeding in your house?" (categorized as referred practices

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162   in the S1.A File). The interviews were conducted using the head of family as the informant.

Risk Observational Assessment

164   In 2017 and 2018, through the application of a structured, standardized and pre-coded household

165   observational checklist (S1.A File), we collected information about risk factors for vector

166   proliferation at the domestic level i.e., unprotected water deposits (vases, flowerpots, cans, tires,

167   drinking troughs, buckets, tank, water tank, cistern etc.), accumulation of solid organic and inorganic

168   waste and others environmental elements (debris, trash, plants, animals). The observations were made

169   in the exterior space of the household, or *patio* (courtyard), where the kitchen, dinning room and

170   rustic bathroom were generally located. Interior space was generally compounded by 1 to 2 bedrooms

171   and a common space (for the television set). In the villages, the *patio* (courtyard) was then a

172   fundamental extension of the house [30]. (These observations are categorized as observed practices

173   in S1).

Community Background Survey

175   In 2018, through precoded and semi-structured questions (S1.B File) to household residents and key

176   informants, respectively, we assessed the presence of risk factors for *Aedes* breeding in the

177   community. The questions focused on the sanitation and hygiene services i.e. the existing facilities

178   for waste collection, the source and frequency of water supply.

179   The semi-structured questions were used to triangulate the information recorded in the domiciliary

180   visits, undertaking interviews with six key informants from each community (nursing staff of the

181   local health center, *Presidente del Comisariado Ejidal*, *ejidal* committee of health). During the

182   interview, we also collected qualitative data to explore risk perceptions and community's expectations

183   about arboviral diseases and their prevention.

Data management and analysis

185 The fieldwork of data collection was realized by trained staff and internal students from ECOSUR,

186 Andalusian School of Public Health and Touro University of California.

187 Information was collected through paper questionnaires. Quantitative data was entered (twice) into a

188 database, using spreadsheets files. All data files were checked and cleaned separately by field

189 supervisors. The data files of all study phases were first analyzed separately. Subsequently, they were

190 merged and analyzed together.

191 Qualitative data from the community background survey were written as field notes, initially by hand,

192 immediately during or directly after the interview process. The information was then organized,

193 through a data collection template, according to the main themes explored (sanitation and water

194 services; perceptions about arboviral disease risk factors and its prevention). Data was described and

195 analyzed in order to identify common or recurrent patterns among the explored themes.

Knowledge, referred and observed practice score system development

197 In order to evaluate each section of the proposed surveys, we created indices (S1.A File) to score the

198 knowledge and practices in question, as was already designed in several previous studies [26-30].

199 Questions related to knowledge only allowed a correct answer. Each correct answer was rated 1 point.

200 Questions related to practices, allowed several correct answers, so that each interviewee had up to

201 five possible options. Each correct answer was rated with 0.5 points. In any case, the wrong answers,

202 or lack of answer, were rated with 0 points. Direct observations, made in the interior and exterior

203 spaces of dwelling unit, focused on two aspects: presence of unprotected water deposits and detection

204 of organic or inorganic solid waste. 1 point was assigned when these elements were absent (observed

205 practices adequate), 0 points if not. A knowledge or practice was considered appropriate when the

206 "overall score" obtained was equal or greater than 60% of the maximum expected score.

Statistical analysis

208 With the data collected, we describe the results with mean and proportions for continuous and

9

209 categorical variables, respectively. Then, we performed univariate and bivariate categorical statistical

210 analysis. Finally, we fitted a logistic regression model to explore social and environmental risk factors

211 associated with the reported arbovirosis knowledge and practices. We derived the odds ratios (OR)

212 and their respective 95% confidence intervals (CI) and assessed goodness of fit using the Hosmer and

213 Lemeshow statistical test. For all the statistical analysis we used R version 3.2.1 (R Foundation for

214 Statistical Computing, Vienna, Austria) and the R Commander package version 2.4-4.

215 **Ethics statement**

216 The research project proposal was approved by the internal review board of the XXXIII Master in

217 Public Health of the Andalusian School of Public Health and the Research Ethics Committee of

218 ECOSUR, with reference number CEI-006-2018. According to article 23 of the General Health Law

219 for Health Research of the Ministry of Health of Mexico [31], due to the nature of the investigation,

220 only verbal informed consent was applied.

221 To conduct the first part of the fieldwork (Household surveys and Risk observation assessment in

222 June 2017), the authors from ECOSUR have received funding by the "Fondo de investigación

223 científica y desarrollo tecnológico de El Colegio de la Frontera Sur (FID 784), in the context of the

224 "Mosquito-MT project". The second part of the fieldwork was undertaken as part of a Public Health

225 Master's Dissertation [32].

226

227 # Results

228 ## Sociodemographic characteristics

229 Table 1 shows the study sample sociodemographic characteristics by locality of residence. In the

230 majority of households the average number of inhabitants was of three of more people (82,5%).

231 Overall, the most common type of family was "young", represented by a mean age for the household

10

232 composition members of less than 35 years old (55%). There were no significant differences in

233 education level, sex and age distribution between the localities of the two municipalities.

234 **Table 1. Sociodemographic characteristics** (Households Survey and Community Background Survey)

	Tapachula (n=82)		Villahermosa (n=67)		Global (n=149)		
	N	%	N	%	N	%	*p value*
Residents per household							
1-2	17	20.7	9	13.4	26	17.4	*0.503*
3-4	33	40.2	29	43.3	62	41.6	
>4	32	39.0	29	43.3	61	40.9	
Women per household							
0-1	28	34.1	20	29.9	48	32.2	*0.843*
2-3	41	50.0	35	52.2	76	51.0	
>3	13	15.9	12	17.9	25	16.8	
Average of women per houseld							
<50%	58	70.7	48	71.6	106	71.1	*0.902*
≥ 50 %	24	29.3	19	28.4	43	28.9	
Family typology (average age)							
Young (<35 años)	40	48.8	42	62.7	82	55	*0.089*
Adult and old (>35 años)	42	51.2	25	37.3	67	45	
Average education (≥15 year old)							
Without schooling	11	13.4	4	6.0	15	10.1	*0.186*
Elementary incomplete	17	20.7	12	17.9	29	19.5	
Elementary	32	39.0	37	55.2	69	46.3	
Advanced (secondary and higher)	22	26.8	14	20.9	36	24.2	
Female average education (≥15 year old)							
Without formal education	12	15.2	8	11.9	20	13.7	*0.919*
Basic (primary) incomplete	16	20.3	16	23.9	32	21.9	
Basic	32	40.5	27	40.3	59	40.4	
Advanced (secondary and higher)	19	24.1	16	23.9	35	24.0	
Solid waste collection services							
Daily	0	0	0	0	0	0	*0.000*
Weekly	0	0	65	97	65	43.3	
Monthly	82	100	2	3	84	56.7	
Water supply services							
Regular	0	0	0	0	0	0	*0.000*
Irregular	0	0	54	80.6	54	36	
Absent	82	100	13	19.4	95	64	
Drainage system							
Present	0	0	0	0	0	0	*NA*
Partial	0	0	0	0	0	0	
Absent	82	100	67	100	149	100	

235

Community background contextualization

237 Significant difficulties in community sanitation were detected, since the frequency of solid waste

238 collection by the municipal services was always monthly in Tapachula and mostly weekly (97%) in

239 Villahermosa. We also found important problems in the water supply services, completely absent in

240 Tapachula and mostly irregular (80.6%) in Villahermosa, as well as a complete absence of a public

241   drainage system in both sites.

242   Both in Villahermosa and in Tapachula, the wells (private or communal) were indicated by all the

243   informants as the main solution to solve the lack of piped water. In *Ejido* Hidalgo, the lack of a

244   functioning community well, even forced those families without other resources to store rainwater.

245   Furthermore, a high level of discomfort and preoccupation was detected, especially with the issue of

246   waste management, as reported by a member of the Rio Florido *Comisariado ejidal*: "Before, there

247   were no such problems. Each family consumed what they had. Now everything comes in plastic,

248   packaging, and then we do not know what to do with so many things. There is a payment landfill, but

249   it is only for families that can afford it." Three of the six informants defined the situation as

250   "[institutional] abandonment". In addition, four of them expressed the perception of an increased risk

251   of infection for the community ("There are more and more mosquitoes" / "more and more people get

252   sick"/ "this has already become a problem"), as well as the perception of greater difficulty in

253   complying with preventive measures. As one member of health staff expressed: "The most important

254   thing is to keep the *patios* clean. It is a task of the whole community, we all must do it to make it

255   work. This is why it is very difficult."

Knowledge and referred vector control practices

257   Table 2 describes the scores about knowledge and practices, as determined by the Household survey.

258   Almost all of the respondents had heard of the diseases (99.3%), and knowledge about arboviruses

259   and their transmission was generally good (75.2%), especially in relation with DENV (81.2%).

260   However, only in few cases (30.7%) adequate personal (how to protect themselves from mosquito

261   bites) or home (how to avoid mosquitoes breeding in and around houses) prevention measures were

262   reported.

263   **Table 2. Knowledge and referred practices (**Household Survey)

	Tapachula (n=82)		Villahermosa (n=67)		Global (n=149)		
	N	%	N	%	N	%	*p value*

12

Had heard about DENV,ZIKV,CHIKV							
Yes	81	98.8	67	100	148	99.3	*0.364*
No	1	1.2	0	0	1	0.7	
Where?							
Television	20	24.7	30	44.8	50	33.8	*0.000*
Neighbors	18	22.2	14	20.9	32	21.6	
Health center	17	21.0	15	22.4	32	21.6	
Disease exposure	22	27.2	0	0.0	22	14.9	
Other	0	0.0	2	3.0	2	1.4	
Perceived prevalence							
Yes	62	75.6	22	32.8	84	56.4	*0.000*
No	20	24.4	45	67.2	65	43.6	
Knowledge							
Adequate (global)	64	78	48	71.6	112	75.2	*0.368*
Inadequate (global)	18	22	19	28.4	37	24.8	
Dengue							
Adequate	67	81.7	54	80.6	121	81.2	*0.255*
Inadequate	15	18.3	13	19.4	28	18.8	
Chikungunya							
Adequate	63	76.8	49	73.1	112	75.2	*0.210*
Inadequate	19	23.2	18	26.9	37	24.8	
Zika							
Adequate	58	70.7	43	64.2	101	67.8	*0.311*
Inadequate	24	29.3	24	35.8	48	32.2	
Referred practices							
Adequate (global)	31	38.6	14	20.9	45	30.7	*0.019*
Inadequate (global)	51	61.4	53	79.1	104	69.3	
Personal protection							
Adequate	13	16.2	9	13.4	22	15.2	*0.701*
Inadequate	69	84.3	58	86.6	128	84.8	
Home protection							
Adequate	44	53	22	32.8	66	44.4	*0.013*
Inadequate	38	47	45	67.2	84	55.6	

264

Observed practices

266 As Table 3 shows, both in 2017 and in 2018, a high proportion of households was found to have some

267 unprotected water containers in outdoors areas (Tapachula: 73.7% and 42.1%; Villahermosa: 58.2%

268 and 54.5% respectively), as well as waste accumulation (Tapachula: 60.5% and 65.8%; Villahermosa:

269 36.4% and 30.3% respectively). In 2017, Villahermosa's village showed a higher percentage of

270 adequate practices than in Tapachula's villages (56.1% and 18.4%, p-value<0.001). However, in 2018,

271 observed good practices showed an increase in Tapachula's villages, from 18.4% to 27.6%. Besides,

272 this change is completely associated with the decrease of unprotected water deposits, since the amount

273 of organic and inorganic waste recorded in 2018 was even higher than in 2017. In Villahermosa's

274 village, the adequate observed practices slightly decreased from 56.1% to 42.4%, in relation with an

13

275 increase of unprotected water deposits and waste in 2018. It is interesting to observe that the

276 percentages of adequate practices in both sites are not significantly different in 2018 (p-value=0.064).

277 **Table 3. Observed practices** (Risk Observational Assessment)

| | 2017 | | | | | 2018 | | | | |
| | Tapachula, (n=76) | | Villahermosa, (n=66) | | | Tapachula, (n=76) | | Villahermosa, (n=66) | | |
	N	%	N	%	*p-value*	N	%	N	%	*p-value*
Adequate[1]	14	18.4	37	56.1	*0.000*	21	27.6	28	42.4	*0.064*
Inadequate[2]	62	81.6	29	43.9		55	72.4	38	57.6	
Unprotected water deposits										
Absent	20	26.3	28	41.8	*0.050*	44	57.9	30	45.5	*0.138*
Present	56	73.7	39	58.2		32	42.1	36	54.5	
Solid waste accumulation										
Absent	30	39.5	42	63.6	*0.375*	26	34.2	46	69.7	*0.000*
Present	46	60.5	24	36.4		50	65.8	20	30.3	

278 [1]Adequate: absence of unprotected water and/or waste.
279 [2]Inadequate: presence of water and/or waste accumulation.

Logistic Regression Model

281 Table 4 shows the results of logistic models for the association between respondent sociodemographic

282 characteristics and reported knowledge and practices. Higher education levels were associated with

283 better knowledge and prevention scores. Household with uncompleted studies had 4-times (OR: 4.13;

284 95% CI: 1.2-13.9) higher probability of inadequate knowledge about arboviruses compared with

285 household with primary or high studies, as well as higher probability of inadequate observed practices,

286 both in 2017 (OR: 38.33; 95% IC: 7.87-186.53) and 2018 (OR: 15.04; 95% IC: 3.89-58.05).

14

Table 4. Respondent sociodemographic characteristics and reported knowledge and practices

	Knowledge (2017)					Referred practices (2017)					Observed practices (2017)					Observed practices (2018)				
	A, n(%)	Ina, n(%)	p	OR	CI	A, n(%)	Ina, n(%)	p	OR	CI	A, n(%)	Ina, n(%)	p	OR	CI	A, n(%)	Ina, n(%)	p	OR	CI
Residents per household																				
1-2	16 (61.5)	10 (38.5)	0.067	1 (R)		4 (15.4)	22 (84.6)	0.911	1 (R)		3(11.5)	23 (88.5)	0.009	1 (R)		6 (24.0)	19 (76)	0.418	1 (R)	
3-4	52 (83.9)	10 (16.1)		0.30	0.10-0.87	11 (17.7)	51 (82.3)		0.84	0.24-2.93	22 (36.7)	38 (63.3)		0.22	0.06-0.83	20 (35.1)	37 (64.9)		0.58	0.20-1.69
>4	44 (72.1)	17(27.9)		0.62	0.23-1.62	9 (15.0)	51 (85.0)		1.03	0.28-3.70	26 (46.4)	30 (53.6)		0.15	0.04-0.55	23 (39.0)	36 (61.0)		0.49	0.17-1.42
Women per household																				
0-1	31 (64.6)	17 (35.4)	0.003	1 (R)		9 (18.8)	39 (81.2)	0.463	1 (R)		1 (23.9)	35 (76.1)	0.073	1 (R)		12 (26.1)	34 (73.9)	0.320	1 (R)	
2-3	66 (86.8)	10 (13.2)		0.27	0.11-0.67	13 (17.3)	62 (82.7)		1.10	0.43-2.81	28 (38.9)	44 (61.1)		0.49	0.21-1.12	27 (38.6)	43 (61.4)		0.56	0.25-1.27
>3	15 (60.0)	10 (40.0)		1.21	0.44-3.29	2 (8.0)	23 (92.0)		2.65	0.52-13.36	12 (50.0)	12 (50.0)		0.31	0.11-0.89	10 (40.0)	15 (60.0)		0.53	0.18-1.49
Average of women per household																				
<50%	32 (74.4)	11 (25.6)	0.892	1 (R)		9 (20.9)	34 (79.1)	0.319	1 (R)		11 (26.8)	30 (73.2)	0.561	1 (R)		10 (25.0)	30 (75.0)	0.125	1 (R)	
≥ 50 %	80 (75.5)	26 (24.5)		0.94	0.42-2.13	15 (14.3)	90 (85.7)		1.58	0.63-3.96	40 (39.6)	61 (60.4)		0.55	0.25-1.24	39 (38.6)	62 (61.4)		0.53	0.20-1.27
Family typology (average age)																				
Young[1]	63 (76.8)	19 (23.2)	0.603	1 (R)		14 (17.3)	67 (82.7)	0.698	1 (R)		36 (46.8)	41 (53.2)	0.003	1 (R)		34 (44.2)	43 (55.8)	0.010	1 (R)	
Adult[2]	49 (73.1)	18 (26.9)		1.22	0.57-2.56	10 (14.9)	57 (85.1)		1.19	0.49-2.88	15 (23.1)	50 (76.9)		2.90	1.33-6.55	15 (23.4)	49 (76.6)		2.56	1.17- 5.80
Average education (≥15 year old)																				
Without[3]	29 (65.9)	15 (34.1)	0.057	4.13	1.23-13.90	13 (36.1)	23 (63.9)	0.072	0.81	0.90-3.49	3 (4.8)	39 (95.2)	0.000	38.33	7.87-186.53	3 (7.3)	38 (92.7)	0.000	15.04	3.89-58.05
Elementary	51 (73.9)	18 (26.1)		2.82	0.87-9.09	15 (21.7)	54 (78.3)		2.03	0.83-4.95	26 (40.0)	39 (60.0)		2.87	1.22-6.76	27 (41.5)	38 (58.5)		1.67	0.73-3.82
Advanced[4]	32 (88.9)	4 (11.1)		1 (R)		18 (40.9)	26 (59.1)		1 (R)		23 (65.7)	12 (34.3)		1 (R)		19 (54.3)	16 (45.7)		1 (R)	
Female average education (≥15 year old)																				
Without[3]	28 (69.2)	16 (30.8)	0.492	1.77	0.64-4.91	20 (38.5)	32 (61.5)	0.400	1.07	0.42-2.72	5 (10.2)	44 (89.8)	0.000	51.03	13.56-192.06	0	49 (100)			Inf.
Elementary	45 (76.3)	14 (23.7)		1.24	0.44-3.46	16 (27.1)	43 (72.9)		0.64	0.25-1.60	17 (30.4)	39 (69.6)		13.30	4.40-40.24	22 (40.0)	33 (60)			
Advanced[4]	28 (80.0)	7 (20.0)		1 (R)		10 (28.6)	25 (71.4)		1 (R)		29 (85.3)	5 (14.7)		1 (R)		26 (76.5)	8 (23.5)		1 (R)	
Solid waste collection services																				
Monthly	64 (78.0)	18 (22.00)	0.367	1.40	0.66-2.96	33 (38.8)	52 (61.2)	0.013	0.40	0.17- 0.87	14 (17.9)	64 (82.1)	0.000	6.17	2.75-14.52	21 (26.9)	57 (73.1)	0.035	2.09	0.99-4.53
Weekly	48 (71.6)	19 (28.4)		1 (R)		13 (20.0)	52 (80.0)		1 (R)		37 (57.8)	27 (42.2)		1 (R)		28 (43.8)	36 (56.2)		1 (R)	
Water supply services																				
Absent	72 (75.8)	23 (24.2)	0.815	0.91	0.40-2.14	34 (35.4)	62 (64.6)	0.092	0.52	0.22-1.18	18 (20.5)	70 (79.5)	0.000	6.02	2.69-13.93	21 (23.6)	68 (76.4)	0.000	3.60	1.64-8.01
Irregular	40 (74.1)	14 (25.9)		1 (R)		12 (22.2)	42 (77.8)		1 (R)		33 (61.1)	21 (38.9)		1 (R)		28 (52.8)	25 (47.2)		1 (R)	
Perceived prevalence																				
Yes	66 (78.6)	18 (21.4)	0.274	1 (R)		13 (15.7)	70 (84.3)	0.836	1 (R)		24 (30.0)	56 (70.0)	0.095	1 (R)		30 (38.5)	48 (61.5)	0.303	1 (R)	
No	46 (70.8)	19 (29.2)		1.51	0.71-3.20	11 (16.9)	54 (83.1)		0.91	0.37-2.19	27 (43.5)	35 (56.5)		0.55	0.26-1.17	19 (30.2)	44 (69.8)		1.44	0.67-3.13

A: Adequate, Ina: Inadequate, *p*: *p value*, CI: CI95%, R: Reference

[1] < 35 years old [2] > 35 years old

[3] Without schooling or incomplete [4] Secondary and higher

292   Likewise, a higher percentage of domestic risk practices were detected in association with significant

293   deficiencies in sanitation and water supply services. When the frequency of solid waste collection

294   was monthly, a higher risk of inappropriate observed practices was detected, compared to the weekly

295   collection (2017: OR: 6.17, 95% CI: 2.75-14.52) (2018: OR: 2.09 95% CI: 0.99-4.53). Similar results

296   were observed in relation to the absence of a water supply network, compared to its presence, even if

297   irregular (2017: OR: 6.02, 95% CI: 2.69-13.93) (2018: OR: 3.60, 95% CI: 1.64-8.01).

Discussion

Principal findings and comparison with other studies

300   Reduction of *Aedes* vector population from the domestic environment is essential to control

301   arboviruses transmission. It is basically achieved through the elimination of any larval habitat, since

302   the domestic and peri-domestic *Aedes* infestation depends on their presence and quantity [13, 30].

303   Our findings suggest that social and environmental contexts influence the development of risk

304   behaviors for vector breeding at the household level. In addition to the educational level, intermediate

305   social determinants, such as water supply and environmental sanitation, are related with the

306   persistence of risk factors for the proliferation of arboviruses.

307   Several studies evidenced the high impact of most of the socio-demographics determinants we

308   described on domestic vector breeding risk [33-35]. In the context of Mexico, gaps in coverage of

309   water and waste services was already identified as key factor for arbovirosis endemicity and the

310   persistence of recurrent outbreaks [36, 37]. A study conducted in Cuba identified a significant

311   association between irregularities in water supply and *Aedes* larval infestation indices [33].

312   Furthermore, outdoor water containers have been reported as the most productive vector breeding

313   sites [38].

314   In our study, participants had high levels of knowledge regarding the transmission of DENV, CHIKV,

16

315   ZIKV, but the overall score about self-reported and observed practices was generally low. Similar

316   findings have been previously described in other localities with recent history of the disease [28, 29,

317   35, 39, 40]. These outcomes suggest that knowledge does not necessarily lead to adequate prevention

318   practices, especially in those contexts where the complex interactions of environmental and social

319   determinants increased human vulnerability to vector borne diseases [11, 12].

320   Community empowerment processes are a fundamental step to enable populations at risk (through

321   behaviors and practices) to lead the eradication of vectors from their environment [15, 25]. There is

322   previous evidence of the effectiveness of community-based approach strategies for the prevention of

323   arboviral disease based on serological and entomological data [41-43]. The household risk

324   observation assessment applied after the community engagement plan in Tapachula revealed a

325   decrease in the accumulation of unprotected water deposits in the dwellings, as well as an increase in

326   the accumulation of solid waste. Although it would be risky and inappropriate to propose a complete

327   evaluation of the community engagement interventions, it seems that its potential impact, in particular

328   on waste accumulation, could have been affected by contextual circumstances. These described

329   circumstances were a high percentage of domestic risk practices detected in association with

330   significant deficiencies in sanitation and water supply services. In Villahermosa's village, where no

331   community engagement plan has been operated, the sanitation services (water and waste collection)

332   are more frequent than in Tapachula; and it is maybe why the residents of Villahermosa showed better

333   practices than Tapachula's residents in 2017.

334   In the semi-structured interviews, was recognized the importance of community involvement

335   (especially at the household level) for the resolution of a problem perceived as growing, similar to

336   the results of previous studies with a qualitative approach to the topic [44, 45].

337   Nevertheless, the difficulties expressed by the key members of the community during the interviews

338   revealed the difficulty of translating preventive measures into everyday actions and behaviors.

17

Limitations of the study

We are aware that our study instruments, chosen according to the available logistic and material resources, are not exempt from limitations. Surveys about knowledge and practices, due to their extension and quantitative approach, impeded a deep understanding of these dimensions and their interaction. Likewise, the categorization of survey data through a scoring system may not be the most appropriate method to approach such a complex issue, which is difficult to measure and quantify.

Furthermore, the reduced size and data sparsity regarding the surveys quantitative information possibly may have influenced a reduced statistical power for the statistical inferential analysis for some of the estimates associations.

Conclusions and implications

We conclude that the endemicity of the arboviral infection in southern Mexico is the result of complex interactions between vector, environment and human behaviors. In order to develop targeted vector control programs to the southern Mexican area, a better understanding of the interactions between environment, vector and host human behaviors is needed. To achieve effective, sustainable, and ethical vector control strategies, a more comprehensive and contextualized approach is required. Community empowerment is more than just information: it is about facilitating and encouraging stakeholders to take control action, through strategies adapted to local conditions and needs. Furthermore, intermediary social determinants of water and sanitation need to be addressed to reduce community vulnerability to the arboviral disease [8-12].

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368

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505

Supporting information

507   **S1 File – Surveys**

24

508   **A. Household survey and Risk observational assessment.** Sections and simplified scoring system.

509   **B. Community background survey.** Adaptation of the pre-coded questions and semi-structured

510   interview guide.