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Support for vector control strategies in the United States during the Zika outbreak in 2016: The role of risk perception, knowledge, and confidence in government☆

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ABSTRACT

Limiting the spread and impact of Zika was a major global priority in 2016, which required a variety of vector control measures. The success of vector control campaigns is varied and often dependent on public or political will. This paper examines the change over time in the United States population's support for vector control and the factors that predicted support for three vector control strategies (i.e., indoor spraying, outdoor spraying, and use of larvacide tablets) during the 2016 Zika outbreak in the United States. Data is from a nationally representative random digit dial sample conducted at three time points in 2016. Bivariate and multivariate regression analyses were used, treating data as a pooled cross-sectional sample. Results show public support for vector control strategies depends on both perceived risk for disease and knowledge of disease characteristics, as well is confidence in government to prevent the threat. Support varied based on vector control method: indoor spraying, aerial spraying, and use of larvacide tables. Results can aide public health officials in implementing effective vector control campaigns depending on the vector control strategy of choice. Results have implications for ways to design effective prevention campaigns in future emerging infectious disease threats.

1. Introduction

In recent years there has been a global rise of arthropod-borne viruses, particularly centered on those vectored by the mosquito species *Aedes albopictus* and *Aedes aegypti*, and a corresponding emphasis on public health strategies to limit the spread of these diseases (Gubler, 2006). Aedine species are the responsible vector for many arboviruses, including Yellow Fever, Chikungunya, Dengue and Zika (Morrison et al., 2008). In February 2016, the World Health Organization declared a global health emergency due to the outbreaks of Zika in the Americas, reflecting the latest example of an Aedes transmitted epidemic (Oussayef, 2017). Zika has been found to cause microcephaly and other neurological defects among newborns in over twenty countries since re-emerging in 2015, and there is evidence it will continue to evolve (Organization WH, 2016; Mlakar et al., 2016). Limiting the spread and impact of Zika has become a priority for many nations, and the virus sparked a variety of approaches to mosquito vector controls, encompassing chemical, biological, and educational strategies to reduce viral transmission (Oussayef, 2017; Fauci and Morens, 2016; Yakob and Walker, 2016).

In many instances, public health officials rely on time-sensitive vector control measures to mitigate the impact of emerging infectious diseases (Yakob and Walker, 2016; Likos, 2016; McCarthy, 2016). Many of these vector control strategies, such as aerial spraying of chemicals or introduction of genetically modified organisms, require public or political endorsement before implementation (McCarthy, 2016; Gubler, 1998). Even when endorsement is not necessary, negative public opinion can impede successful vector control campaigns (Morrison et al., 2008; Paek et al., 2008; Tedesco et al., 2010). Public health communication campaigns associated with these vector control strategies can be as important as the environmental strategies themselves (Holmes, 2008). Therefore, it is critical for public health officials to understand the factors that can lead the public to impede or embrace vector control strategies (Holmes, 2008). In a variety of frames in both the health and hazards literature, such as the Health Belief Model, Social Cognitive Theory, Extended Parallel Processing Model, and Protective Action Decision Model, public acceptance of public health interventions and responsiveness to risk communication is built on acquiring knowledge, having intention for behavior change, and engaging in behavior change in the context of social cues (Becker, 1974; Buldeo and Gilbert, 2015; Kramer et al., 2014; Lindell and Perry, 2012; Lorenz et al., 2011; Weinstein, 1993; Ibuka et al., 2010). The goal of this article is to explore the knowledge and risk-related predictors of support for such interventions, so that public health communicators can better manage public support when combating an emerging infectious disease, such as Zika.

☆ The authors have nothing to disclose.

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1.1. Vector control approaches

There are a variety of mechanisms for vector control of mosquito-borne infections, oriented around three key principles: 1) prevent the propagation of the viral mosquito population, 2) remove the current mosquito population, and 3) reduce human exposure (Spiegel et al., 2005; Achee et al., 2015; Bouzid et al., 2016). To prevent the propagation of the viral mosquito population, biologic agents and genetic modification of vectors is often considered by scientists and policy maker. Many of these strategies seek to reduce the larvae population and include use of larvacide tablets, biological agents like larvivorous fish, copepods, predatory insects, or *Bacillus thuringiensis israelensis* (Bti), a bacterium that produces toxic proteins lethal to aedine larvae (Bouzid et al., 2016; Rather et al., 2017). To remove the existing mosquito population, health officials rely on insecticide sprays and larvacide sprays which are placed in standing water or tablets (Likos, 2016). Also aiming to reduce human exposure, local authorities promote educational campaigns on draining and covering standing water areas on residential properties (Likos, 2016). While these approaches are ecologically sound and reduce mosquito populations generationally, they require significant community engagement because individuals themselves are asked to take action (Sommerfeld and Kroeger, 2015; Al-Muhandis and Hunter, 2011).

Though the long-term goal for vector control is to prevent proliferation of infectious vector populations, in an emerging outbreak public health officials must move quickly to reduce risk and viral load in high transmission areas. This need for rapidity when strategies targeting the virus itself are underdeveloped often means public health officials favor the approaches that remove the current mosquito population through outdoor or indoor spraying (Bouzid et al., 2016). Over the course of the global Zika epidemic, countries including Brazil, Puerto Rico, Cuba, and the United States relied on diverse strategies to combat the virus depending on the burden of disease and cultural context, many of which included mosquito reduction tactics (Fauci and Morens, 2016; Likos, 2016). For these reasons, exploring the factors associated with support for vector control is relevant and helpful for improving public health practice.

1.2. Support for vector control

Notwithstanding the ubiquity of such mosquito reduction approaches, their public acceptance is not always assured. This may be due to a variety of factors including, political will, community support, and environmental setting (Tedesco et al., 2010; Spiegel et al., 2005). Historically, in the United States there has been backlash or concern regarding strategies employed to control mosquitoes (Kinkela, 2016). During the 2012 West Nile Virus outbreak in Northern Texas, which spanned four counties, only two counties engaged in aerial spraying due to public concerns and political will (Piltch-Loeb et al., 2014). In 2016, when Zika appeared in Miami, aerial spraying was delayed 24 h due to large protests against the use of naled (Cáceres, 2016). In the same year, Orange County, California residents opposed and prevented a referendum that would have allowed the Manager of the County's Vector Control agency unilateral power to spray pesticides aerially in the event of an outbreak (Chandler, 2016). Other vector control strategies have been criticized, as well. In a community-based survey on the potential use of GM mosquitoes, Adalja and colleagues found that a majority of Florida Keys locals did not support this method of vector control and ultimately GM mosquitos were not introduced (Adalja et al., 2016). Lack of support was correlated with low perception of the risks of extant mosquito-born viruses, the female gender, and low concern about controlling mosquito populations, in general (Adalja et al., 2016).

As these examples highlight, lack of endorsement of vector control can impede the success of public health efforts. In contrast, public support can improve the success of a public health intervention making it more timely, widespread, and long lasting (Gubler and Clark, 1996). However, mitigation strategies that are the least invasive, are often least effective, and more acceptable to the public (Diepeveen et al., 2013). In a global health emergency, like the Zika virus in 2016, it is imperative that public health officials have the necessary support to implement comprehensive and successful interventions to control a crisis of confidence in the public and effectively mitigate the risk of infection (van der Weerd et al., 2011). Despite this, little is understood about the characteristics associated with public support (Azoh Barry, 2014). Understanding these factors can assist public health officials in designing more effective public information campaigns. This analysis presents the results of a repeated, representative, cross-sectional study of U.S. residents collected at three time points between April 2016 and November 2016, and considers the predictors of support for environmental strategies to control Zika. These findings will contribute to the limited literature on predictors of support for vector control and aid public health practitioners in developing more effective strategies for impacting public opinion and answer three related research questions:

1. How did receptivity to vector control activities change as more information on Zika became available?
2. How did public support for the use of public health vector control strategies vary by vector control method?
3. To what extent were factors drawn from the theoretical literature including source of information, confidence in government, risk perception, and knowledge associated with support of vector control methods?

2. Methods

2.1. Theoretical framework

There is a vast literature on risk communication as well as likelihood of behavior change employed in public health (Brewer et al., 2007; Rudisill, 2013). In this analysis the authors draw on constructs that have been proposed in both literatures to examine the behavior of vector control receptivity, and the relevant predictors, given the high risk, emerging environment created by the rise of the Zika virus. The Protective Action Decision Model, a communication framework linked to behavioral outcomes served as the basis for this analysis (Lindell and Perry, 2012). The model asserts that individuals are influenced by various cues when confronted with a threat which in turn relate to a person's risk perception and knowledge, and then their likelihood of supporting an outcome. The model also posits there are key modifiers to receptivity such as political support (Lindell and Perry, 2012). Therefore, drawing on this model, the authors sought to understand if risk perception, knowledge, and source of information were key factors associated with intervention receptivity. Confidence in government, a potential moderator in PADM was also tested for its association with intervention receptivity, due to the role of the government in implementing vector control strategies. Further detail on how the authors have applied theoretically derived constructs can be found in a prior manuscript by the authors(Piltch-Loeb et al., 2017).

2.2. Data collection

Data comes from a representative survey of U.S. households collected using a fully-replicated, single-stage, random-digit-dialing (RDD) sample of households supplemented by a list of randomly generated cell phone numbers, conducted to rapidly survey and understand population perspectives on the emerging Zika threat. The survey was conducted at three time points: Spring (April/May, $n = 1233$), Summer (July/August, $n = 1231$), and Fall (October/November $n = 1234$) of 2016 to identify population level changes over time. All samples were weighted to the US population. The AAPOR response rate was approximately 4% at each wave with an average number of seven calls for completes, consistent with trends in representative survey research

(Dutwin and Lavrakas, 2016; Kohut et al., 2012). The sample frame included an oversampling of women of child-bearing age between the ages of 18–45 living in the southern tier states of Florida, Alabama, Mississippi, Louisiana, and Texas, as a sub-population at higher risk than the general population.

2.3. Measures

2.3.1. Outcome measures

The authors assessed public receptivity to three potential public health campaigns: community-wide outdoor spraying of insecticides; indoor spraying of insecticide by local officials; and provision of larvacide tablets to residents to be deployed on personal property. Respondents were asked their level of support for each intervention. In regard to outdoor and indoor spraying, individuals were asked "The following are actions that the government might take to control the Zika virus, do you agree or disagree with… "Receptivity was then dichotomized so that those who were very likely or somewhat likely to support the intervention were coded as receptive and those who were somewhat or very unlikely to support the intervention were coded as not receptive to the intervention.

2.3.2. Independent variables

Knowledge of Zika, risk salience, confidence in government, and media cues were the four constructs tested for their associations with environmental intervention receptivity. Respondents were coded as knowledgeable if they knew that the Zika virus could be sexually transmitted, could be carried asymptomatically, and could cause birth defects, as these items reflected three key characteristics about the Zika virus. Each knowledge element was a binary variable tested in models. Perceptions of personal Zika risk and community Zika risk were based on self-report of respondents, and were dichotomized (1 = at risk; 0 = not at risk). Confidence in government was dichotomized as confident government can address the Zika epidemic vs. not confident based on the question "How confident are you that the government can address problems associated with Zika?" Those who said not very confident or not confident at all were put into the null category. The cues are measured as sources of information individuals used for Zika information. Per the theoretical model, the cues are hypothesized to operate through knowledge to intervention receptivity. They are included here to identify if there are any independent effects of cue on the outcome. Respondents described the sources of information they accessed for information on Zika and further identified which was their primary source. For analytic purposes, the eight primary sources were recoded into four categories: 1) informal sources, which encompassed social media, family, and friends; 2) formal news sources, which included print, online, and broadcast news; 3) personal physicians; and, 4) government communications.

2.3.3. Control variables

The authors controlled for sociodemographics characteristics including age (18–29 (ref.); 30–45; 46–64; 65 +), gender (male (ref.); female), region (Gulf Coast (ref.); Mid-US; North), race (Non-Hispanic White (ref.); Non-Hispanic Black; Hispanic; Other), household income (less than $25,000 (ref.); $25,000–49,999; $50,000–99,999; more than $100,000), education (less than high school (ref.); HS/GED; some college; 4-year college) and political party identification (Republican (ref.); Democrat; Independent).

2.4. Analytic plan

The research team first examined change over time in intervention receptivity and key independent variables. Unadjusted and adjusted logistic regression were applied to test the association of independent variables of interest with each environmental public health intervention. The model included controls for demographic, socio-economic, regional, and political views, as bivariate analyses suggested that these factors were likely relate to intervention receptivity and potentially influence the relationship among knowledge or risk, and receptivity. All analyses used weighted data with significance levels set at the $p < 0.05$ level. Researchers conducted analyses using Stata statistical software, version 14. The Institutional Review Board of the author's academic institution approved the research.

Table 1
Changes over time in key dependent and independent variables among those aware of Zika, Waves 1, 2, and 3.

	Wave 1	Wave 2	Wave 3	Total	*p*-value
	%	%	%	%	
Knowledge of sexual transmission					0.8242
No	48.11	49.65	48.28	48.68[a]	
Yes	51.89	50.35	51.72	51.32	
Knowledge of asymptomatic infection					0.6173
No	33.67	31.2	32.97	32.59	
Yes	66.33	68.8	67.03	67.41	
Knowledge of birth defects					0.1047
No	9.91	13.9	12.51	12.17	
Yes	90.09	86.1	87.49	87.83	
Believe personally at risk for Zika					0.9731
No	65.75	66.34	65.91	66	
Yes	34.25	33.66	34.09	34	
Believe community at risk for Zika					0.0288
No	39.89	43.44	47.19	43.71	
Yes	60.11	56.56	52.81	56.29	
Receptive to outdoor spraying					0.7641
No	21.26	20.9	22.41	21.52	
Yes	78.74	79.1	77.59	78.48	
Receptive to indoor spraying					0.5791
No	61.76	59.76	59.23	60.23	
Yes	38.24	40.24	40.77	39.77	
Receptive to Larvacide					< 0.001
No	28.1	35.19	39.3	34.19	
Yes	71.9	64.81	60.7	65.81	

[a] Table reflects the results of a chi-squared test of knowledge, risk, or receptivity by wave. *P*-values refer to statistically significant differences in average level by wave.

3. Results

To answer the first two research questions, Table 1 shows the percentage of the population which supported each public health intervention and how this support changed over time. Overall, the public was most receptive to outdoor spraying by the government (78.5%), and there were no significant differences over time. Over 65% of the population indicated were receptive to using larvacide tablets on their personal property, though the support for this intervention significantly decreased at each time point (Wave 1–71.9%, Wave 2–64.81%, Wave 3–60.7%). Overall, 39.8% of the population supported the use of indoor spraying by the government, and there were no significant changes over time. The distribution and change in independent variables of interest is also shown in Table 1. Knowledge that Zika can be sexually transmitted was consistent between 51 and 52% over the course of the year. Knowledge that Zika can be an asymptomatic infection did not significantly change over the course of 2016, holding around 67%. Knowledge Zika can cause birth defects ranged from 90 to 86%. Knowledge of birth defects was highest among the three knowledge items. Sense of personal risk (approximately 34%) did not change throughout 2016; however, sense of community risk decreased from the first survey to the third survey (from 60.1% to 52.8%).

To address the third research question, Table 2 presents the

Table 2
Weighted multivariate logistic regressions for the association between Zika interventions and knowledge, risk perceptions, and covariates among those aware of Zika.

	Crude odds ratio for indoor spraying	Adjusted odds ratio for indoor spraying	Crude odds ratio for outdoor spraying	Adjusted odds ratio for outdoor spraying	Crude odds ratio for Larvacide	Adjusted odds ratio for Larvacide
	OR (CI)	OR (CI)	OR (CI)	OR (CI)	OR (CI)	OR (CI)
Confident government can address Zika issue						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.78 (1.49, 2.14)	1.77 (1.38, 2.28)	1.93 (1.57, 2.38)	1.96 (1.44, 2.66)	1.80 (1.50, 2.15)	1.77 (1.36, 2.31)
Knowledge of sexual transmission						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.25 (1.04, 1.50)	1.28 (1.01, 1.63)	1.77 (1.41, 2.23)	1.52 (1.13, 2.06)	1.27 (1.05, 1.54)	1.25 (0.97, 1.79)
Knowledge of asymptomatic infection						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.18 (0.97, 1.45)	1.10 (0.85, 1.45)	1.20 (0.95, 1.53)	1.25 (0.90, 1.73)	1.04 (0.85, 1.27)	1.13 (0.85, 1.50)
Knowledge of birth defects						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.18 (0.87, 1.61)	1.01 (0.68, 1.52)	1.51 (1.08, 2.12)	1.34 (0.83, 2.18)	1.35 (1.00, 1.81)	1.16 (0.75, 1.79)
Wave						
1	Ref	Ref	Ref	Ref	Ref	Ref
2	1.09 (0.88, 1.34)	1.19 (0.91, 1.60)	1.02 (0.79, 1.32)	1.07 (0.74, 1.53)	0.72 (0.58, 0.90)	0.74 (0.54, 1.02)
3	1.11 (0.90, 1.37)	1.11 (0.85, 1.45)	0.93 (0.73, 1.20)	0.84 (0.58, 1.21)	0.60 (0.49, 0.75)	0.56 (0.41, 0.77)
Believe personally at risk for Zika						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.06 (0.88, 1.29)	0.98 (0.75, 1.29)	1.03 (0.81, 1.32)	1.15 (0.81, 1.62)	1.61 (1.31, 1.98)	1.40 (1.02, 1.90)
Believe community at risk for Zika						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	0.93 (0.77, 1.12)	0.90 (0.69, 1.17)	0.87 (0.69, 1.10)	0.77 (0.55, 1.09)	1.62 (1.34, 1.97)	1.39 (1.04, 1.86)
Primary source of information on Zika						
Family/friends/social media	Ref	Ref	Ref	Ref	Ref	Ref
News/Tv/radio	0.86 (0.68, 1.09)	0.92 (0.65, 1.30)	1.74 (1.32, 2.27)	1.21 (0.78, 1.86)	0.96 (0.75, 1.22)	0.84 (0.56, 1.25)
Doctor	0.85 (0.54, 1.34)	0.77 (0.33, 1.76)	0.93 (0.57, 1.52)	2.33 (0.81, 6.74)	0.73 (0.46, 1.14)	0.68 (0.26, 1.77)
Government	0.77 (0.44, 1.32)	0.59 (0.29, 1.18)	1.41 (0.69, 2.86)	0.76 (0.31, 1.90)	1.30 (0.70, 2.43)	1.06 (0.42, 2.66)

Tables control for race, age, region, gender, political affiliation, income, and education.

weighted univariate and multivariable logistic regression for the association between Zika intervention and key independent variables. All adjusted models controlled for sociodemographic characteristics- education, age, income, race, region and gender and time of data collection. In the adjusted model examining factors associated with support for outdoor spraying, knowledge of sexual transmission (OR 1.52, CI 1.13, 2.06) and confidence in government (OR 1.96, CI 1.44,2.66) both significantly increased the odds of intervention support. There were no adjusted effects of information cues on the odds of support for outdoor spraying. Factors associated with support for indoor spraying in the adjusted model also included knowledge of sexual transmission (OR 1.28, CI 1.01, 1.63) and confidence in government (OR 1.77, CI 1.38, 2.28). There was no adjusted relationship with information cues and the odds of support for indoor spraying. The odds of support for larvacide were related to confidence in government (OR 1.77, CI 1.36, 2.31), perceived personal risk for Zika (OR 1.40, CI 1.02, 1.90) and perceived community risk for Zika (OR 1.39, CI 1.04, 1.86). There was again no relationship between information cues and the odds of using larvacide on personal property.

4. Discussion

The authors set out to examine three research questions to contribute to the limited literature on factors associated with support of vector control. To answer the first question, the authors explored to what extent did the public support the use of public health vector control activities as the Zika virus emerged and how did support vary by vector control method. Of the environmental intervention strategies proposed to combat Zika by various public health officials, individuals were most receptive to outdoor spraying (78.5%) followed by the use of larvacide tablets (65.8%), and then indoor spraying (39.8%). Outdoor spraying has historically been the most common intervention, and therefore, may be the one most familiar to individuals (Adalja et al., 2012). Outdoor spraying is also not commonly found to impact personal property.

The second question asked how receptivity to vector control activities changed as the evidence and concerns on Zika evolved throughout 2016. Among this representative sample of U.S. residents, there was little change in public receptivity for these environmental interventions over time, despite local transmission of Zika in both Florida and Texas. Use of larvacide was the only intervention strategy where support significantly decreased over time (between waves) from 71.9% to 60.7%. This could be because the use of larvacide tablets on personal property was less discussed in the media and therefore perceived as less necessary, or because the use of larvacide is less common or familiar than the use of spraying of insecticide. Knowledge of Zika's characteristics also remained relatively unchanged over time. The authors suggest two reasons this may be the case. First, portions of the population that had heard of Zika were already aware of its characteristics at the time of our first survey, and additional information was filtered out. Second, because local transmission of Zika was of very limited concern, the population was most attuned to Zika information around birth defects, which have the highest dread, and less concerned with other disease characteristics like transmission.

The third question pertained to theoretically derived constructs that have been hypothesized in the literature or prior research to relate to intervention receptivity or behavior change including confidence in government, risk perception, and knowledge. Looking across interventions, the only consistent predictor of support for indoor spraying, outdoor spraying, and use of larvacide tablets was confidence in government to respond to the Zika epidemic. Confidence in government significantly increased the odds of support across all interventions, suggesting a key driver for all environmental vector control strategies that were proposed to combat the Zika virus. Prior studies have identified level of education, community engagement, and social capital as individual factors that are positively associated with confidence in government (van der Weerd et al., 2011; Blind, 2007; Bults et al., 2010). This suggests that potentially engaging with community prior to attempting to implement a vector control strategy could shift confidence in government and potentially public support for multiple intervention approaches. Specific approaches may vary but could include educational campaigns on ongoing public health activities or town hall meetings to stay connected to the community.

Receptivity to indoor spraying and outdoor spraying by the government were both driven by knowledge that Zika can be sexually transmitted. Knowledge was found to increase the odds of intervention support for both indoor and outdoor spraying, suggesting that recognition of sexual transmission may influence the population to government action. The lack of a significant relationship between risk perception and receptivity to intervention further demonstrates that the population does not need to identify as at risk to support intervention if there is other disease knowledge. In contrast, use of larvacide was the only intervention where risk perception- both at the community and individual level increased the likelihood of use and there was no relationship between knowledge and the outcome. This may be because use of larvacide on personal property required the most direct individual action, so individuals had to feel personally at risk to engage in this behavior. Source of information was not directly related to interventions. This may be because information operates through knowledge or risk.

There are limitations with this study. First, the response rate was low, though consistent with representative phone surveys, this requires weighting procedures that can make estimates more unstable. Confidence in government to address the Zika epidemic may be a linked to a variety of factors that are not explicitly measured in this study. The research team controlled for political affiliation, and is thus confident this factor is not simply a measure of how political climate relates to intervention receptivity, but rather faith in government activities. This survey focused exclusively on attitudes towards vector control for the Zika virus, while the research team believes there are similarities across mosquito-borne viruses in public attitudes, further analysis is necessary to confirm if these results would be replicated.

Mosquito-borne viruses like Zika are emerging and re-emerging due to the globalization of trade and travel, to shifting weather patterns, and to land development practices (Morrison et al., 2008; Gubler, 1998). The Zika virus in particular has a viral genome that changes over time leading to ongoing spikes in cases(Metsky et al., 2017). Localities within the United States have to be prepared to combat these vectors, and public support is critical for implementing effective strategies. Identifying the factors that drive public support for vector control, especially spraying, can aide professionals in successfully implementing transmission prevention strategies (Tedesco et al., 2010; Covello et al., 2001). This paper identifies some of these factors with particular attention to the role of confidence in government, knowledge, and risk perception. These intervention specific results suggest additional areas for targeted risk communication to increase knowledge to promote either indoor or outdoor spraying. The success of control measures does not rest on intervention effectiveness alone, but rather on the public's willingness to accept the intervention (Paek et al., 2008). Therefore, public health officials must focus on both public opinion and vector control simultaneously. With the public as a key force in the success of a vector control campaign to limit the spread of disease, these results suggest activities before the implementation of vector control strategies to increase confidence in governmental response, could increase public support for interventions in an outbreak. Further research should explore the optimal mechanisms to do this.

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