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Willingness to Pay for Mosquito Control in Key West, Florida and Tucson, Arizona

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Abstract. Mosquito-borne illnesses like West Nile virus (WNV) and dengue are growing threats to the United States. Proactive mosquito control is one strategy to reduce the risk of disease transmission. In 2012, we measured the public's willingness to pay (WTP) for increased mosquito control in two cities: Key West, FL, where there have been recent dengue outbreaks, and Tucson, AZ, where dengue vectors are established and WNV has been circulating for over a decade. Nearly three quarters of respondents in both cities (74% in Tucson and 73% in Key West) would be willing to pay $25 or more annually toward an increase in publicly funded mosquito control efforts. WTP was positively associated with income (both cities), education (Key West), and perceived mosquito abundance (Tucson). Concerns about environmental impacts of mosquito control were associated with lower WTP in Key West. Expanded mosquito control efforts should incorporate public opinion as they respond to evolving disease risks.

Mosquito-borne viruses cause a high level of morbidity and mortality worldwide.[1] West Nile virus (WNV) is transmitted by *Culex* mosquitoes and is currently the leading cause of mosquito-borne disease in the United States. Since its emergence in 1999, cases have occurred in all 48 continental states, and a total of over 1,700 deaths have been attributed to WNV.[2] Meanwhile, dengue viruses, transmitted primarily by *Aedes aegypti* mosquitoes, are a growing threat in the southern United States, with recent outbreaks occurring in Florida and Texas.[3–5] As neither vaccines nor therapeutics are yet available for dengue or WNVs, mosquito control is the primary option to prevent and control outbreaks of both diseases.

This report focuses on residents' willingness to pay (WTP) for increased mosquito control in two cities with variable mosquito-borne virus histories and mosquito control activities: Key West, FL and Tucson, AZ. In 2009–2010, an outbreak of 93 dengue cases occurred in Key West, FL,[3] but WNV transmission has never been reported. The Florida Keys Mosquito Control District operates an active and aggressive control strategy in Key West, targeting oviposition sites using ground and helicopter distribution of *Bti*, as well as targeted spraying of adulticides, with stated goals of enhancing quality of life and reducing disease risks.[6] Tucson is located in Arizona, a state with consistently higher than average incidence of WNV but no reported autochthonous transmission of dengue.[7] Tucson's dengue risk is uncertain. *Aedes aegypti* is abundant, and each year nearly 10 million people cross the border into nearby Nogales, AZ from dengue endemic regions in Mexico and Central America making this area vulnerable to local introduction of the virus.[8] However, Tucson conducts only limited mosquito control activities. Until recently, routine surveillance was conducted using only CO_2 traps that target *Culex* mosquito species, the vectors of WNV. In 2015, however, ovitraps and BG-Sentinel traps for *Ae. aegypti* were added to the surveillance practices. Residential control measures are limited to source reduction in response to mosquito complaints (G. Aguirre, personal communication). No broad-scale use of adulticiding, such as ultra-low-volume spraying, is conducted due to public safety concerns and limited budgets.

Knowledge, attitudes, and practices surveys were carried out in these two cities in the summer of 2012. In Key West, residential and mixed residential/business parcels were randomly selected for survey recruitment. In Tucson, given the comparatively large size of the city, a cluster survey was conducted using random sampling of 1) 20 neighborhoods at least one mile apart, and then 2) parcels within selected neighborhoods. In both cities, surveys were conducted in-person, and recruitment was conducted at two different times of day on weekends and weekdays to obtain a sample that represented individuals with various work schedules. If participation was declined or there was no response at the household after two attempts, replacement households were selected using a systematic procedure. Timing of data collection in both cities coincided with rainy seasons, when mosquito densities are highest.[9,10] The study protocol and survey instrument were approved by the Institutional Review Board of the University of Arizona (protocol number 11-0709-00).

The surveys included an extensive set of questions on knowledge and awareness of mosquito-related diseases, with a particular focus on dengue in Key West and both dengue and WNV in Tucson. Following these questions, a module was included to measure WTP for a hypothetical expansion of mosquito control efforts. Respondents were told:

> *Suppose that there was a proposal to expand mosquito control in the Keys so that the number of mosquitoes in this area would be cut in half. The types of control methods would be the same as what is currently used, but control would be done more often and in more places. To fund this expansion, your household (and other households in [the Keys/Tucson]) would be charged a fee of $100 per year.*

Respondents who said "yes" were asked if they would still support the proposal if the fee were increased to $150, and respondents who agreed to this amount were asked if they would still support the proposal if the fee were $200. Respondents who said "no" to the initial $100 fee were asked if they would support the proposal if the fee were lowered to $50; if they said no to this amount, they were asked about their support if the fee were $25. This constitutes a triple-bounded dichotomous choice contingent valuation format (as in Langford and others[11]). Responses to these questions provide a WTP range for each respondent.

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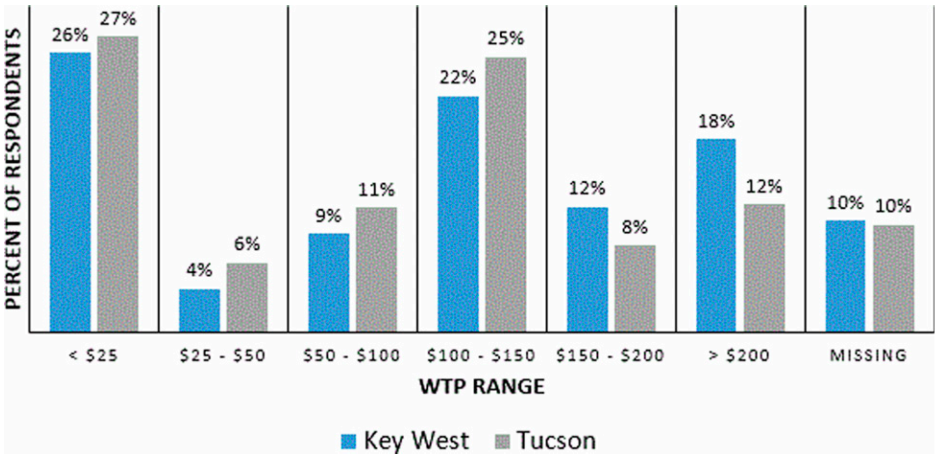

FIGURE 1. Willingness to pay for mosquito control by city.

The starting bid of $100 was chosen based on survey pretesting, consultation with local mosquito control officials, and reference to other studies of WTP for mosquito control.[12] The economic literature on contingent valuation has shown that the selection of a starting bid can alter respondents' final WTP amounts, such that ideally, multiple starting bid amounts would have been randomized across respondents.[13] However, due to logistical constraints, we were not able to run multiple survey versions with different starting bids. We acknowledge this as a limitation of the study design. WTP results presented here should not be interpreted as definitive measures of the value of mosquito control within these populations, but rather as one set of estimates that can be compared across two cities and used to analyze within-city differences based on observed respondent characteristics, described below.

The distribution of WTP responses for the two cities is plotted in Figure 1. Overall, WTP for expanded mosquito control was somewhat higher in Key West compared with Tucson (Pearson's χ^2 statistic = 11.7, P = 0.04). The proportion of respondents who were not willing to pay any of the proposed fees is roughly equal across the two cities: 26% in Key West compared with 27% in Tucson.† However, over half of respondents (51%) in Key West were willing to pay at least $100, compared with 45% in Tucson, and nearly one in five Key West respondents (18%) said that they would be willing to pay $200 (12% in Tucson).

Note that these WTP values were for increases in mosquito control above existing levels, which differed greatly between the two cities. The total budget for the Florida Keys Mosquito Control District was $14.7 million in 2011–2012, funded through ad valorem taxes, which equates to roughly $500 per household per year (28,503 households in the Florida Keys in 2010). Meanwhile, Tucson's vector control activities do not have specific funding and fall under the Consumer Health and Food Safety Program. This suggests that total demand for mosquito control was much higher in Key West compared with Tucson, despite the apparent similarity in the incremental WTP values measured by the two surveys.

We also examined variation in WTP across respondents within each city using interval censored regression. In these regressions, the dependent variable was the WTP range, which is censored at the low and high ends of the scale since in these cases we do not know the lower or upper bound, respectively, on WTP.‡ In addition, we conducted binary logistic regression analyses using membership in the highest WTP category (> $200) as the dependent variable. In each of these multivariate regressions, a set of respondent characteristics described in Table 1 were included as independent variables. Results are summarized in Table 2. We found that:

- *Higher socioeconomic status was linked to higher WTP in both cities*. Income was positively associated with WTP in both Key West and Tucson, and education was also positively associated with WTP in Key West.
- *Other demographic factors were linked to WTP in Tucson, but not in Key West*. In Tucson, both older respondents and respondents with children under 5 years in the household expressed lower WTP.
- *Perceived mosquito abundance was associated with higher WTP for mosquito control in Tucson*. Respondents who said they noticed "A moderate amount," "Quite a few," or "Very many" (versus "None" or "Very few") mosquitoes in their neighborhoods at the time of the survey also indicated higher WTP amounts.
- *Environmental concerns may have led to somewhat lower WTP among some respondents in Key West*. Respondents in Key West who expressed concerns about the environmental impacts of mosquito control were less likely to say that they were willing to pay the highest tax amount ($200).

Several other variables, including prior awareness of dengue and WNV and spending more time outdoors, were not significantly associated with WTP in either city.

†Debriefing questions asking respondents about their reasons for their responses were not included in the survey. This is another limitation of the study design, preventing us from, for example, distinguishing "protest zeros" (i.e., expressions of zero WTP due to objections to the choice question or the payment mechanism) from "true zeros."

‡A natural lower bound would be $0, but WTP could even be negative—that is, it is possible that some respondents would need to be compensated in order for them to accept increased mosquito control.

TABLE 1
Descriptive statistics for independent variables in willingness to pay analyses

Variable	Description	Descriptive statistics: Value	Key West	Tucson
Age	Age of respondent	Mean	51	49
		Median	53	49
		Range	18–93	18–97
		Declined	13 (3%)	11 (3%)
Female	Respondent is female	Yes	183 (46%)	198 (53%)
		Declined	3 (1%)	5 (1%)
Children under 5 years	Number of children under 5 years in the household	0	341 (85%)	310 (82%)
		1	34 (9%)	46 (12%)
		2	12 (3%)	14 (4%)
		3+	4 (1%)	1 (0.25%)
		Declined	9 (2%)	5 (1%)
Nonwhite	Respondent indicated race as other than "White"	Yes	76 (19%)	173 (46%)
		Declined	31 (8%)	0 (0%)
Latino	Respondent indicated that they were Latino	Yes	77 (19%)	165 (45%)
		Declined	25 (6%)	0 (0%)
English	Respondent's primary language is English	Yes	353 (88%)	312 (83%)
		Declined	11 (3%)	0 (0%)
Education	Respondent's education category	Less than high school	30 (8%)	37 (10%)
		High school	93 (23%)	59 (16%)
		College	203 (51%)	202 (54%)
		Graduate/Professional	63 (16%)	71 (19%)
		Declined	11 (3%)	7 (2%)
Income	Household income category (imputed for missing data)*	Less than $35,000	82 (21%)	118 (31%)
		$35,000–$49,999	39 (10%)	82 (22%)
		$50,000–$74,999	91 (23%)	81 (22%)
		$75,000–$99,999	105 (26%)	34 (9%)
		$100,000 or more	83 (21%)	61 (16%)
Heard of dengue	Respondent indicated that he/she had heard of dengue prior to survey	Yes	308 (77%)	158 (42%)
		Declined	0 (0%)	4 (1%)
Know someone with dengue	Respondent indicated that he/she knew someone who had dengue (asked in Key West only)	Yes	94 (24%)	
		Declined	4 (1%)	
Heard of West Nile	Respondent indicated that he/she had heard of West Nile virus prior to survey	Yes	28 (7%)	323 (86%)
		Declined	0 (0%)	0 (0%)
Know someone with West Nile	Respondent indicated that he/she knew someone who had West Nile virus (asked in Tucson only)	Yes		22 (6%)
		Declined		4 (1%)
Notice many mosquitoes	Respondent indicated that he/she noticed "A moderate amount," "Quite a few," or "Very many" (vs. "None" or "Very few") mosquitoes in neighborhood at time of survey	Yes	188 (47%)	131 (35%)
		Declined	23 (6%)	6 (2%)
Time outdoors	Respondent indicated that he/she typically spends an hour or more outdoors less than 3 days/week	Yes	101 (25%)	113 (30%)
		Declined	2 (0.5%)	4 (1%)
Concerned about environment	Respondent indicated that he/she was concerned about environmental impacts of mosquito control	Yes	39 (10%)	21 (6%)
		Declined	0 (0%)	1 (0.25%)
Concerned about health	Respondent indicated that he/she was concerned about human health impacts of mosquito control	Yes	60 (15%)	47 (13%)
		Declined	0 (0%)	1 (0.25%)

*Because a large proportion of respondents declined to provide data on household income (39% missing in Key West and 18% in Tucson), imputed data are used for this variable. Multiple imputation was performed using an imputation by chained equations process with the software package IVEware. Briefly, 1,000 datasets were created that imputed all missing information based upon responses to demographic information and mosquito/dengue knowledge.

Overall, results indicate that in two cities with different mosquito-transmitted disease exposure, the majority of the population was willing to pay to support increased publicly funded mosquito control. However, several issues would need to be addressed before such expansions of control efforts were implemented. First, given variation in WTP by socioeconomic status, paying attention to equity issues in the design of any program and payment scheme would be important. We do note that even in the lowest income groups, however, the proportion of respondents willing to pay at least $25 was fairly high (68% in Key West and 64% in Tucson).

Second, attention to the types of control methods used in each city would be required. Addressing residents' concerns about the environmental impacts of proposed methods would be important, as we find that these concerns are related to WTP in Key West, possibly due to the active mosquito control program in this city and residents' firsthand knowledge of several control methods (including adulticide spraying). In addition, WTP values were based on the assumption that the scaled up program would cut mosquito densities in half. These values would likely need to be adjusted depending on the actual results that could be expected from a proposed program.

TABLE 2
Multivariate regression analyses of factors associated with WTP for mosquito control in Key West and Tucson

	Key West		Tucson	
	WTP (interval regression)	WTP ≥ \$200 (binary logit)	WTP (interval regression)	WTP ≥ \$200 (binary logit)
Age	0.12 (0.45)	0.0074 (0.0092)	−1.52*** (0.37)	−0.035*** (0.012)
Female	−11.7 (14.9)	0.056 (0.30)	13.7 (0.37)	0.24 (0.38)
Children under 5 years	5.40 (17.7)	0.34 (0.32)	−27.1** (10.7)	−0.77* (0.40)
Nonwhite	−13.5 (20.6)	0.066 (0.45)	14.3 (17.4)	0.28 (0.55)
Latino	4.79 (20.5)	0.32 (0.41)	−11.0 (17.4)	−0.50 (0.63)
English	−5.60 (35.3)	0.64 (0.75)	−8.44 (19.5)	−0.32 (0.61)
Education: HS vs. less than HS	45.1 (31.3)	15.9*** (0.25)	2.10 (25.3)	−0.23 (0.76)
Education: college vs. less than HS	48.6 (31.4)	16.2*** (0.13)	9.34 (24.2)	−0.37 (0.75)
Education: graduate/professional degree vs. less than HS	79.5** (35.8)	16.9*** (0.28)	26.8 (29.9)	0.50 (0.86)
Income	13.3** (5.46)	0.14 (0.11)	20.6*** (5.11)	0.37** (0.15)
Heard of dengue	−5.74 (22.9)	−0.17 (0.44)	8.76 (13.3)	−0.13 (0.42)
Know someone with dengue	−0.52 (0.33)	−0.018 (0.013)		
Heard of West Nile	11.9 (28.4)	0.20 (0.52)	−0.32 (18.8)	0.12 (0.54)
Know someone with West Nile			2.84 (18.6)	−1.49 (1.05)
Notice many mosquitoes	22.0 (15.6)	0.34 (0.30)	19.5* (11.6)	−0.12 (0.37)
Spend 1 hour outside less than 3 days/week	−14.9 (18.2)	−0.14 (0.37)	−4.10 (13.4)	0.016 (0.40)
Concerned about environment	−37.5 (25.9)	−1.53** (0.63)	3.62 (25.2)	−1.25 (1.16)
Concerned about health	24.4 (24.6)	0.49 (0.39)	−3.62 (19.6)	−0.23 (0.66)

WTP = willingness to pay. Robust standard errors in parentheses.
*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

Third, a final design question for mosquito control programs involves the types of mosquitoes that are targeted. Different surveillance and control methods are needed to target WNV (*Culex*) versus dengue virus (*Aedes*) vectors. Furthermore, nuisance and quality of life concerns influence WTP as well as demand for disease risk reduction. For example, another study in Madison, WI, estimated WTP for control of nuisance mosquitoes at \$150 per respondent per year, but average WTP for control programs solely targeting WNV vectors was \$0 given current levels of disease risk (about one case per 250,000 residents in 2009). The Key West/Tucson study did not separately measure demand for disease risk reduction versus nuisance reduction, but our findings provide hints that nuisance may be an important motivator in these contexts as well: while disease knowledge variables were not significant predictors of WTP in either city, households in Tucson that noticed more mosquitoes were willing to pay more for control. As the threat of both dengue and WNV evolve over time, however, disease risk may loom larger in the public's mind and WTP for mosquito control may increase.

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