

WILLINGNESS-TO-PAY FOR AN AREA-WIDE INTEGRATED PEST MANAGEMENT PROGRAM TO CONTROL THE ASIAN TIGER MOSQUITO IN NEW JERSEY

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ABSTRACT. Using contingent valuation we estimated the perceived value of an area-wide integrated pest management program for the Asian tiger mosquito, *Aedes albopictus*, implemented in Monmouth and Mercer counties, NJ. We estimated residents' maximum willingness-to-pay and perceived monetary benefits (willingness-to-pay excluding residents who protested all types of payments) and payment modality through a telephone survey of 51 randomly selected households. The mean (\pm SE) perceived monetary benefits for an enhanced mosquito abatement program was \$9.54 \pm 2.90 per capita per year. Most respondents would have been willing to pay through taxes (35%) or charitable donations (6%) starting then, or through one of these approaches in the future (43%), whereas 16% were completely unwilling to pay any additional costs whatsoever. We projected that the perceived monetary benefits to the counties' 1.01 million residents for an enhanced mosquito control program would be \$9.61 million annually. Thus, collectively residents perceived monetary benefits of 3.67 times the combined 2008 annual operating costs of the counties' existing mosquito control programs of \$2.61 million.

KEY WORDS Mosquitoes, control methods, willingness to pay, health economics, prevention and control, KAP (knowledge, attitude, practice), vector biology

INTRODUCTION

Aedes albopictus (Skuse), known commonly as the Asian tiger mosquito, is a day-biting, black and white mosquito, native to East and South Asia, and abundant in the tropics. Since the 1980s, *Ae. albopictus* has expanded its presence in countries on several continents, including the USA (Benedict et al. 2007). This mosquito was introduced into the USA repeatedly (Pratt et al. 1946, Eads 1972, Reiter and Darsie 1984), becoming established following shipments of used tires to Texas in 1985 from northern Asia (Moore

and Mitchell 1997). Currently, this species infests 30 states and continues to spread (CDC 2005).

Since its discovery in New Jersey in August 1995 (Crans et al. 1996), this species has been a nuisance to residents and has been recognized by public health officials as a potential vector of nearly 30 arboviruses (Gratz 2004), including Japanese encephalitis, dengue's 4 serotypes, and yellow fever, as well as the nematode dog heartworm (*Dirofilaria immitis* (Leidy)) (Crans 1996). Reports indicate that *Ae. albopictus* in the USA has been infected with several arboviruses, including Cache Valley, eastern equine encephalitis, Jamestown Canyon, La Crosse, and West Nile (Moore and Mitchell 1997, Gerhardt et al. 2001, Turell et al. 2005, Farajollahi and Nelder 2009). Although its role as a major disease vector in New Jersey has not yet materialized, laboratory research indicates that *Ae. albopictus* could function as an efficient vector of endemic arboviral diseases in the state (Crans 1996; Turell et al. 2005; CDC 2012a, 2012b). Additionally, the dengue outbreaks in Hawaii in 2001 (Efler et al. 2005) and 2011 (Fujimori 2011), in France in 2010 (La Roche et al. 2010), and chikungunya virus in Italy in 2007 (Rezza et al. 2007) and in France in 2010 (Gould et al. 2010) highlight the public health danger associated with this species.

Aedes albopictus is considered the most significant nuisance mosquito species across its range due to its propensity to bite humans during the day, producing in some cases dermatological and allergic manifestations. The species is also thought to impact residents' quality of life by forcing adults and children to stay indoors to avoid its aggressive behavior (Hawley 1988). In

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New Jersey, *Ae. albopictus* is currently responsible for the majority of service requests to local mosquito control programs (Unlu et al. 2011). The proportion of complaints associated with *Ae. albopictus* doubled from 29% in 2005 to 62% in 2008 (Farajollahi and Nelder 2009). Although observations in New Jersey associate the species more with urban than rural habitats, in its native range *Ae. albopictus* is associated with rural and forest locations (Hawley 1988).

The standard approaches to mosquito abatement, such as source reduction (i.e., removal of water sources that serve as larval sites), larviciding, adulticiding, and resident education as a component of residents' routine service requests, have achieved only limited effectiveness in controlling this species after its establishment in newly infested areas (Jardina 1990, Wheeler et al. 2009, Unlu et al. 2011). For an urban pest such as *Ae. albopictus* in the northern USA, an area-wide approach is more effective than existing approaches in controlling urban mosquitoes, since the mosquito tends to spread to neighboring properties (Wang 1994). Area-wide integrated pest management (AWIPM) involves coordinating activities over a large area to reduce the overall densities of insect pests, and minimizing the risk of initial infestation and reinfestation after pests have been controlled (Flinn et al. 2003). This approach has proved effective in reducing the population of red imported fire ants (*Solenopsis invicta* (Buren)), black imported fire ants (*Solenopsis richteri* (Forel)), Mediterranean fruit flies (*Ceratitidis capitata* (Wiedemann)), stored-grain insects of rice weevil (*Sitophilus oryzae* (L.)) and lesser grain borer (*Rhyzophertia dominica* (F.)), leafy spurge (*Euphorbia esula* (L.)), Western corn rootworm (*Diabrotica virgifera virgifera* (LeConte)), Northern corn rootworm (*Diabrotica barberi* (Smith and Lawrence)), Mexican corn rootworm (*Diabrotica virgifera zea* (Krysan and Smith)), and codling moth (*Cydia pomonella* (L.)) (Anderson et al. 1999, Hagstrum et al. 1999, Vargas et al. 2001, Calkins and Faust 2003, Chandler 2003, Pereira 2003, Vogt et al. 2003, USDA 2008). Area-wide approaches include 5 major components: assessment, operations/implementation, research, education, and reassessment (Calkins and Faust 2003). The success of such programs depend on pest-specific technologies, such as appropriate surveillance/control methods and tools, as well as appropriate adaptation of community participation techniques (Calkins and Faust 2003, Baly et al. 2009, Farajollahi et al. 2009, Unlu et al. 2011).

Mosquito control is a "public good" in that it provides a community benefit, where successful implementation protects all those in the district to which the control is applied. In this sense, it is a public health service that must be provided collectively to all residents of the target area. To

justify a government intervention, the value of the perceived monetary benefit of such a program can assist policy makers in generating and allocating resources, as well as developing appropriate interventions. To address these challenges, a joint team from Rutgers and Brandeis universities, and Monmouth and Mercer counties in New Jersey has collaborated in a US Department of Agriculture Agricultural Research Service-funded project, "Area-wide integrated pest management of *Aedes albopictus*," with the aim of developing and implementing a multidisciplinary approach to address the *Ae. albopictus* problem in that state as a prelude to extending this approach to other *Ae. albopictus*-infested areas in the USA (USDA 2012).

Using the contingent valuation (CV) method, this paper estimates households' demand for an AWIPM program that can effectively mitigate the potential threat of disease and nuisance from urban mosquito species by significantly reducing the population of *Ae. albopictus* and other urban mosquitoes. The CV approach is a survey-based methodology for eliciting stated preferences using a monetary metric for the valuation of nonmarket resources (such as public goods like environmental preservation) (O'Brien and Gafni 1996, Diener et al. 1998, Olsen and Smith 2001, Hanley et al. 2003, Garming and Waibel 2006). The monetary valuation respondents give in a CV survey is referred to as "willingness to pay" (WTP).

The foundation of CV rests in welfare economics, and is commonly used to evaluate benefits associated with government intervention aiming to correct market failures, and to assist in making a judgment about the desirability of having government undertake particular policies and interventions, in addition to setting priorities among competing public programs (O'Brien and Gafni 1996, Diener et al. 1998, Olsen and Donaldson 1998, Olsen and Smith 2001, Hanley et al. 2003, Garming and Waibel 2006).

Contingent valuation is the most widely accepted method for estimating total economic value for a hypothetical program or a public good. Contingent valuation is superior to other economic outcome measures in that no restrictions are imposed on which attribute of a public program people are allowed to value (Olsen and Donaldson 1998, Wise 2010). Additionally, CV measures benefits in the same units as costs so the results can be used in cost-benefit analysis (Mitchell and Carson 1993, O'Brien and Gafni 1996, Diener et al. 1998, Olsen and Smith 2001, Hanley et al. 2003). Moreover, CV methods and results are relatively easy to analyze and describe.

Much of the criticism against the use of WTP relates to the measurement biases inherent in the study design (Olsen and Donaldson 1998) and the possible difference in the way people make hypothetical decisions relative to the way they

make actual decisions. These limitations can be overcome by appropriately designing CV surveys as behavioral surveys (Smith 2003). The difficulty of validating the estimated values externally (Olsen et al. 2005) is addressed in a recent study, which found no significant difference between the stated and actual WTP (Ramke et al. 2009).

Willingness-to-pay is often criticized for being associated with ability to pay, which might raise equity concerns. However, comparable equity concerns have also been raised about other economic metrics (Williams 1988). Finally, the question of whether individual preferences can be aggregated within a social function is a controversial topic (Mould Quevedo et al. 2009). In the economic literature, the aggregation of individual preferences is generally accepted when convexity is assumed and interpersonal comparison of such preferences is imposed (Hurley 2000, Drummond and McGuire 2001).

In addition to estimating households' perceived monetary benefit of an AWIPM program and their WTP to control urban mosquito species, this study examines the relation of household characteristics and knowledge to expenditure and attitude toward mosquito control.

MATERIALS AND METHODS

Study population

The AWIPM team at Rutgers University and Monmouth and Mercer counties selected 3 neighborhoods in each of Monmouth and Mercer counties as study sites. Monmouth County (population 642,448) consists primarily of coastal suburban townships, whereas Mercer County (population 364,883) contains Trenton, a large, low-income city (US Census Bureau 2009a, 2009b). Each site contained approximately 1,000 parcels (defined as a home and surrounding yard). The 3 selected neighborhoods in each county were similar in their socioeconomic characteristics, such as percentage of high school graduates, percentage of college graduates, percentage of households below poverty level, and median income, topography, and *Ae. albopictus* population density. The study sites in Monmouth and Mercer counties contained 11,806 and 19,494 residents, respectively (Unlu et al. 2011).

Sample frame

The sample frame (listing of land parcels in the study sites) was obtained from public records (primarily tax documents) of Mercer and Monmouth counties. Merging addresses from both counties created a sample frame of 6,303 households. Incomplete addresses, addresses with postal box addresses, and duplicate addresses were removed from the sample frame. The US

Postal Service zip code lookup Web site (<https://tools.usps.com/go/ZipLookupAction!input.action>), Google Maps (<https://maps.google.com>), and Google Earth (earth.google.com) were used to remove nonresidential units (e.g., commercial establishments) and to confirm the physical location of the addresses within the selected study areas. Residents' names and phone numbers were obtained using reverse-lookup Web sites such as White and Yellow Pages (http://www.whitepages.com/reverse_address and <http://www.yellowpages.com>) and were validated by secondary sources such as www.anywho.com. For addresses with both male and female residents, we chose the female based on the assumption that a female resident would be better able to answer both for the household and any elementary school-age children in that household, an important component for the self-administered survey mentioned below.

The sample

The WTP telephone survey complemented a self-administered mailed survey, which collected data on household characteristics, outdoor yard or porch activities, expenditures on personal and household measures to control mosquitoes, and knowledge and attitudes toward personal mosquito management. Using simple random sampling without replacement, 1,350 households were selected to participate in the self-administered postal survey. From these households, 100 were randomly selected from each county to include in the telephone survey component as well.

The postal survey (for 1,350 households) focused on adult respondents as well as a selected elementary school child in their household, if applicable. The telephone survey (200 households) was conducted to obtain the maximum amount a household was willing to pay to support the county mosquito program, and in some cases to complete the response to the previously disseminated postal survey as well.

Survey administration

Graduate students from Brandeis University administered the interviews after an intensive training session. Interviews were conducted in either English or Spanish, based on the respondent's preference, and at a time convenient to the respondent.

Respondents were first contacted about *Ae. albopictus* through an invitation letter mailed at least 1 wk prior to the survey. This letter requested their participation in an upcoming survey concerning outdoor activities and mosquito control. It highlighted the importance of this issue following the introduction of *Ae. albopictus* into New Jersey, which can make outdoor activities unpleasant. In appreciation for their

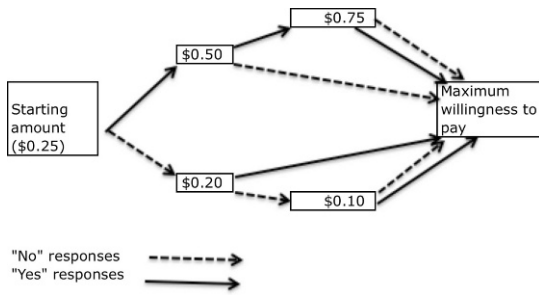


Fig. 1. Willingness-to-pay question: Decision tree starting at \$0.25 for additional amount per month per person to implement the area-wide integrated pest management program. The question asked: Would you be willing to pay the additional amount shown per month per person to implement this program? Similar decision trees for starting values of \$0.75 and \$0.10 were used in some interviews.

time, respondents were also offered \$10 after the completion of the survey.

Survey instrument

To enhance the content validity of the survey instrument, we reviewed literature on similar projects (John et al. 1987, Donaldson 1990, Hausman 1993, Mitchell and Carson 1993, Onwujekwe and Uzochukwu 2004, Salam et al. 2006, Onwujekwe et al. 2008, US Bureau of Labor Statistics 2011), incorporated experts' opinions regarding possible outcomes, and pretested the instrument. The results were used in formulating the CV scenario, the range of bid levels, as well as coming up with appropriate phrasing of questions. The WTP telephone survey was conducted between October 2008 and January 2009. The final telephone interview consisted of 2 main sections concerning the monetary amount of WTP and, if applicable, reasons for unwillingness-to-pay. After receiving an introduction noting the challenges facing urban mosquito control authorities and the potential effectiveness of the AWIPM program, interviewees were asked if they would be willing to support this program financially by paying an additional tax earmarked for this purpose. Respondents with positive answers were asked to state the maximum amount that they were willing to pay through an iterative series of questions as described in the upcoming text. Persons with negative responses to the initial question were asked if they would be willing to support this program financially by making regular charitable contributions. If the answers for both these questions were negative, then these respondents were asked for the reasons for their unwillingness to contribute.

For those willing to contribute for the project, we used a split sample bidding technique to elicit

the maximum amount they would be willing to pay per person per month (PPPM) above and beyond the existing payments for their county's routine mosquito control program (Stalhammar 1996). The sample was divided into 3 components each assigned to one of the starting values: a high value of \$0.75 PPPM, a middle value of \$0.25 PPPM, and a low value of \$0.10 PPPM. This varied starting point controls for possible anchoring bias due to the starting bidding point. The branching logic for these questions is illustrated for the middle starting value in Fig. 1.

Data cleaning and coding

Hours spent engaged in yard or porch activities, hours residents would have spent engaged in yard and porch activities if they had no concern for mosquitoes, as well as household and personal expenses to control mosquitoes were controlled for outliers and inconsistent information. To clean the "hours spent engaged in various yard and porch activities during a typical summer week" and "hours responder would have spent in various yard and porch activities during a typical summer week" variables, all missing values were computed as zero and all hours spent or would have been spent engaged in the 5 yard and porch activities were Winsorized according to their 95 percentiles. Reported expenditures on personal and household measures to control mosquitoes combine recurrent items (such as insect repellents) and capital items, such as purchases of bug zappers, window and door screens, or repair of windows and water pipes. Consistent with standard economic analyses, we amortized these capital items over their useful lives at the recommended real interest rate of 3% per year (Gold et al. 1996).

Analysis

Graduate students coded the survey responses and entered the data into Excel spreadsheets (Microsoft Corporation, Redmond, WA). Ten percent of the sample was reentered to check the consistency and quality of the data entry. Data were then transferred to SPSS (Chicago, IL) for analysis.

Previous literature had shown that "unwillingness to contribute" could be attributed to 2 factors: 1st, the respondent lacked interest in or perceived no value from the program (true zeros); or 2nd, the respondent rejected the tradeoffs implicit in the WTP model. In the latter case, respondents state a zero WTP bid for reasons other than lack of interest in, or perceived no value from the program, such as protest behavior against some component of the question design (e.g., payment mechanism, meaning an aversion to additional taxes, ethical objections, or their personal inability to pay). These zero responses are called protest zero bids and can be differentiated from respondents who state that

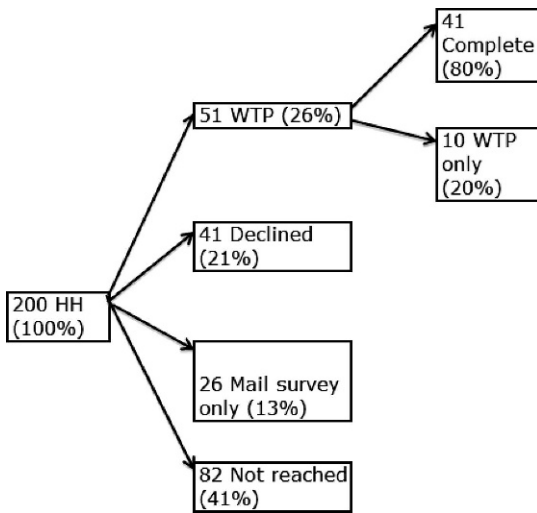


Fig. 2. The sample distribution, Monmouth and Mercer counties, NJ, 2008. WTP, willingness-to-pay; HH, households.

they have no interest in, or do not value the program (true zero bids) (Hanley et al. 2003, Cho et al. 2008).

We differentiated protest zeros from true zeros according to the reasons respondents provided for their unwillingness to contribute to the project. Residents who protested taxes or stated inability to pay were considered protest zeros, whereas those who gave other reasons, such as satisfaction with the current services provided by their counties, were considered true zeros.

Based on this classification of responses, we conducted a 2-part analysis. The first included the protest zeros, whereas the second excluded them. Results were reported as arithmetic and weighted means ($x = \sum_{i=1}^n w_i x_i$, where $\sum_{i=1}^n w_i = 1$), standard deviations (as well as the SE of the means for the maximum WTP amount) for continuous variables, and as frequencies for categorical variables. *t*-tests, ANOVA, and chi-square tests with alpha level of significance at 0.05 were used to test key analyses for comparisons between true and protest zeros.

Table 1. Household characteristics of 2008 willingness-to-pay interviews ($n = 51$).^{1,3}

Variable	% of study counties	% of study selected sites	% of study sample	Significance ^{2,3}
Number of households in each county ($n = 51$)				***
Monmouth ($n = 29$)	64	33	57	
Mercer ($n = 22$)	36	67	43	
Child at home ⁴ ($n = 41$)	33	36	49	NS
Female respondent ($n = 40$)	50	50	88	***
Respondent's age range ($n = 39$)				**
35-44	30	18	18	
45-54	29	19	49	
55-64	22	14	15	
65-74	12	8	15	
75 up	8	8	3	
Respondent's level of education ⁵ ($n = 39$)				NS
Less than 9th grade	8	7	3	
9th-12th grade	12	10	5	
High school graduate	32	34	38	
Some college, no degree	17	18	15	
Associates degree	6	7	5	
Bachelors degree	15	16	28	
Graduate or professional	9	8	5	
Average household size ($n = 41$)	2.83	2.87	3.19	NS
Respondent's employment status ⁶ ($n = 39$)				NS
Working	59	66	64	
Unemployed ⁷	6	6	3	
Not in labor force	35	34	33	

¹ Sources: US Census Bureau (2009a, 2009b).

² ** $P < 0.01$; *** $P < 0.001$; NS, not statistically significant; comparing sample with study sites.

³ Chi square calculated using <http://math.hws.edu/javamath/ryan/ChiSquare.html>.

⁴ Household with one or more people under 18 years.

⁵ Population 25 years and over.

⁶ Population 16 years and over.

⁷ Looking for a job.

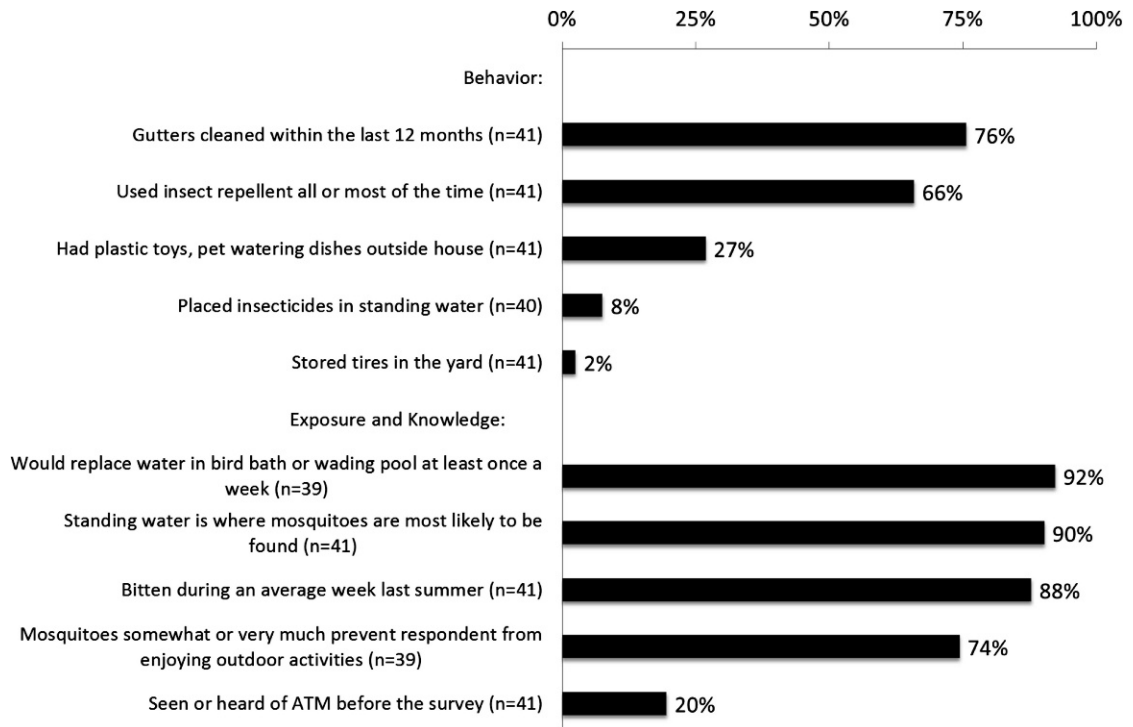


Fig. 3. Respondents' exposure, knowledge, and attitudes toward mosquitoes. Total respondents, $n = 41$; respondents may answer yes to multiple items.

Sensitivity analyses

Two sensitivity analyses were conducted on the overall WTP: the 1st adjusted for population distribution between the 2 counties and the 2nd standardized for age. These analyses were conducted by weighting each respondent's maximum WTP amount by his/her county or age category.

RESULTS

From 200 randomly selected households, 118 (59%) were contacted, whereas 82 (41%) were not reachable due to incorrect phone numbers, names, or addresses. Of those contacted, 51 (26% of overall sample) consented to be interviewed, 41 (21%) declined to participate, and 26 (13%) completed the mail-back survey but not the WTP component. The overall survey response rate was thus 26% (51/200), whereas the interview cooperation rate was 55% (51/92). Interviews were conducted in English (82%) or Spanish (18%). Figure 2 depicts survey responses.

Demographic characteristics

About 57% of respondents resided in Monmouth County and 43% in Mercer County. In addition, 88% were female, 82% were 45 years of age and older, and 49% had at least one child under the age of 18 living in the household. Most

(87%) had at least a high school diploma and 64% were in the labor force, including 3% actively looking for a job. Table 1 compares the household characteristics of the respondents to those of the study area populations and the total population of the 2 counties.

Exposure to mosquitoes, expenditures, knowledge, and behaviors

Respondents reported spending on average (\pm SD) 23 \pm 19 h engaged in outdoor activities per week during the summer. As shown in Fig. 3, 74% of respondents stated that mosquitoes prevented them from enjoying their outdoor yard activities somewhat or very much, and 88% were bitten at least once during an average summer week. Sixty-six percent used insect repellent most of the time during outdoor activities. When asked about household spending to control mosquitoes over the past summer, 76% of the households reported spending on one control measure or another. Their level of spending was skewed, with many small amounts and a few large ones; the mean (\pm SD) total household expenditure to control mosquitoes was \$86.70 \pm 194.70 per annum. Annual amortized expenditures on capital items, such as repair of windows and leaky water pipes and "bug zappers," averaged \$37.80 \pm 159.30. Expenditures on personal mosquito

Table 2. Additional willingness-to-pay (WTP) and current mosquito control budget, Mercer and Monmouth counties, NJ, combined, 2008.

Item	Unweighted	Weighted
No. of respondents	51	51
Average WTP per person per month	\$0.45	\$0.42
Average WTP per person per year	\$5.42	\$5.05
Aggregate WTP per year	\$5,464,000	\$5,089,000
Current budget		
2008 budget per person per year	\$2.60	\$2.60
2008 budget for all mosquito control	\$2,615,000	\$2,615,000
Aggregate annual WTP as multiple of the 2008 budget	2.09	1.95

protection, such as adding insecticides to standing water, spray to repel mosquitoes, and burning “mosquito coils,” averaged \$34.7 ± 102.3 per household. Of those who incurred some expenditure, the average total expenditure was \$114.70 ± 217.30 during that summer, with a minimum expenditure of \$0.60 and a maximum expenditure of \$1,019.

Regarding practices related to development of immature mosquitoes, 2% of respondents reported storing tires in their yards and 27% had plastic containers outside their house; both tires and plastic containers are considered important developmental sites for *Ae. albopictus* (Benedict et al. 2007). Seventy-six percent of respondents had cleaned their gutters at least once within the 12 months prior to the survey, whereas 8% placed insecticides in containers with standing water. Only 20% reported that they had heard about the *Ae. albopictus* mosquito before our survey. The majority of respondents, 90%, correctly answered that mosquitoes are more likely to be found in

standing water than in moving water, and 92% correctly stated that water should be replaced at least once a week in bird baths or wading pools to control mosquitoes. There were no significant differences between the 2 counties on any of the behavior and knowledge questions.

Overall WTP

Willingness to make payments to control urban mosquitoes was endorsed by 41% (21 of 51) of respondents, of whom 86% would accept paying additional taxes earmarked for mosquito control, whereas 14% would make only regular charitable contributions. The unweighted mean of the maximum WTP for all 51 respondents (± SE) was \$0.45 ± 0.14 PPPM, or \$5.42 per capita per year (Table 2). No statistically significant differences were found between counties nor among alternative starting bids for the WTP questions or age groups, so the main results are reported unweighted with all respondents pooled. When extrapolated to the total combined county populations, the aggregate unweighted WTP was \$5.46 million per year, which represents about 2 times the 2008 mosquito control budget for the 2 counties.

Perceived monetary benefit analysis

Figure 4 describes the response process for the WTP survey. Adding the 22 protest zeros and the 8 true zero responses, 30 respondents were unwilling to contribute to the AWIPM program. Among these 30 respondents, 18 (60%) stated that they could not offer to pay for the new program and 4 (13%) protested the payment mechanisms, constituting the protest zeros, whereas 3 (10%) stated that they did not have a mosquito problem, and 5 (17%) stated other reasons. Since protest zeros are not signaling a clear zero value, *t*-test, 1-way ANOVA, and chi-square tests were used to test the differences in demographic characteristics, exposure, expenditure, knowledge, and behavior between protest zeros bids responses and the rest of the sample.

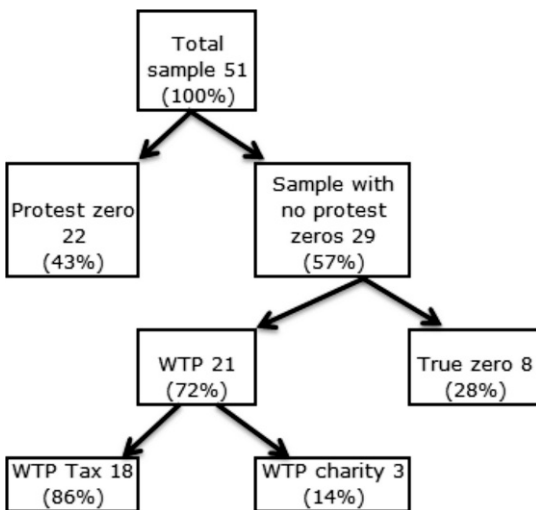


Fig. 4. Numbers of respondents in Monmouth and Mercer counties, NJ, indicating willingness-to-pay (WTP) for area-wide pest control program, 2008.

Table 3. Perceived monetary benefit of an area-wide integrated pest management program per person in Monmouth and Mercer counties, NJ, study sites, 2008.

Item ¹	Both counties
No. of responses excluding protest zero (<i>N</i>)	29
Monthly average WTP excluding protest zero (\$, PPPM)	0.79
SEM (\$, PPPM)	0.24
Annual per capita WTP excluding protest zero (\$)	9.54
SEM (annual)	2.88
Aggregate perceived monetary benefit per year (\$, mean) ²	9,610,000
SEM (\$, aggregate)	2,900,000
Willing to pay through tax mechanism (<i>N</i>)	18
Willing to pay higher tax (% share of respondents excluding protest zero)	62
Estimated number of residents in Monmouth and Mercer counties willing to pay a higher tax	625,000
Aggregate WTP among respondents willing to pay through higher tax (\$, per year)	3,390,000
Average WTP per person willing to pay through tax mechanism (\$)	5.42
2008 budget for all mosquito control (\$)	2,615,000
2008 budget per person per year (\$)	2.60
% increase in tax over 2008 budget	130

¹ WTP, willingness-to-pay; PPPM, per person per month.

² Mean maximum amount respondents in Monmouth and Mercer counties study sites were willing to pay, excluding protest zeros, 2008.

That calculation found no significant differences, and Tobit regression identified no censoring problem; therefore, protest zeros were excluded from the subsequent analyses.

The average WTP (\pm SE) for the 29 respondents who remain after excluding the protest zero responses was \$0.79 \pm 0.24 PPPM in both counties. As shown in Table 3, the potential increase in tax for an enhanced control program suggested by our results could have increased both Monmouth and Mercer County budgets in 2008 by 130% through an additional tax earmarked for this "new" urban mosquito control program. The perceived monetary benefit of this program was 367% of the current mosquito budget for both counties (i.e., \$9,610,000/\$2,615,000).

Sensitivity analyses

The weighted average maximum WTP (\pm SE), weighted by each county's population, was \$0.42 \pm 0.14 PPPM, or \$5.05 per capita per year. As illustrated in Table 2, the results were similar to the unweighted results. Weighting for the population distribution between the 2 counties, the weighted aggregate WTP was \$5.09 million compared to \$5.46 million for the unweighted population. Correcting for the age distribution, the weighted average maximum WTP by age distribution (\pm SE) was \$0.36 \pm 0.12, which yielded an aggregate annual amount of \$4.4 million for both counties.

DISCUSSION

Our findings of perceived monetary benefits in 2 counties in New Jersey suggest that the value of an enhanced mosquito control program may be

\$9.54 per capita per year, or \$9.61 million for these 2 counties. The estimated total perceived monetary benefits associated with the AWIPM were 3.67 times as great as the annual operating costs of the existing mosquito control program in both counties for 2008. Our survey was conducted between October 2008 and January 2009. Since the interviews were conducted in the winter (well after most people would have been bitten by a mosquito), the responses to the interviews should have moderated the possible inflation value residents might express during the "mosquito season" for a monthly taxation or charity contribution to support a year-round program.

Acknowledging the importance of nuisance pests, other studies from the USA support the benefits associated with mosquito control (John et al. 1987, Farmer et al. 1989). A 1987 publication reported that residents of Jefferson County, TX, valued mosquito abatement at \$10.86 per property unit per year in increased taxes per year in excess of their current tax payments, equivalent to about \$7.92 per capita annually in 2008 prices based on the study's average household size of 2.6 persons and 90% cumulative inflation (John et al. 1987, US Bureau of Labor Statistics 2011). A 1989 Arkansas study found a WTP of an additional \$8.49 PPPM for mosquito control, equivalent to \$176.25 per capita annually in 2008 prices based on 73% cumulative inflation (Farmer et al. 1989).

Our results are within the broad range of these previous findings. The potential health threats, the number of residents' complaints, as well as our study findings demonstrate that *Ae. albopictus* interferes substantially with outdoor activities (Farajollahi and Nelder 2009; Healy, unpublished

data). To inform additional government investment in an urban mosquito control program, there is a need to place a value on the perceived monetary benefit of such a program, which will assist policy makers in generating and allocating resources as well as developing appropriate interventions.

In 2008, the operating cost of control of *Ae. albopictus* and other urban mosquitoes was \$2.6 million in Mercer and Monmouth counties combined. Due to the sampling variation in our responses, if we assume that WTP follows a normal (or t) distribution, the lower 95% confidence interval bound on WTP is \$4.67 million, which is substantially above the current budget. This implies that at least an additional \$2.07 million (the difference between this bound and the current program) could be spent to create a program as strong as that specified in our survey. Alternatively, if it were possible to achieve the specified result through a reallocation of the existing budget, our survey shows that it is 98.9% likely that WTP would exceed that cost.

For residents willing to pay something for this program, 86% were willing to pay an additional tax, whereas the remaining 14% were willing to pay by charity only. Our findings imply that for residents willing to support additional taxes for mosquito control, they will be willing to pay an additional \$3.4 million in annual taxes. This analysis indicates that the value placed on mosquito control from residents' perspective is higher than current spending levels, which is consistent with results from the WTP for urban public services literature (USDA 2008, Farajollahi et al. 2009). Residents would accept an increase in the mosquito control budget of 130% to enhance a control program focused on *Ae. albopictus*. In a political context, these findings imply that residents support increased financial allocations for additional mosquito control. This suggests a new control program costing at maximum \$3.4 million per year would be supported if reallocation of existing funds, as well as new taxes, were possible funding mechanisms.

Several limitations to this study must be acknowledged. First, our WTP estimates might be underestimated compared to their long-run values. Our interviews were conducted between October 2008 and January 2009, a period after the peak mosquito season, but one that corresponds to the beginning of the financial downturn in the USA. Uncertainty related to future income might have reduced respondents' willingness to contribute to this program and reduced the maximum amount they are willing to pay. While the survey questions required respondents to identify value benefits that accrue in a different time of the year from when they completed the interview and/or survey, the timing of our survey may have resulted in more

valid responses for a program that requires year-round funding.

Second, due to the challenges faced with the sample frame and the methods used in obtaining residents' names and phone numbers, the sample population was significantly different from the resident population in distribution by age group and county, as shown in Table 1. However, we found that these selection effects did not matter as weighted and unweighted results did not differ significantly. Therefore, we presented our results using the unweighted means for simplicity and higher statistical power.

Third, our survey was based on a hypothetical mosquito control program since the AWIPM had not been implemented prior to our interview survey. If residents actually experienced an effective control program, their WTP could differ from the projections reported here.

Fourth, our sample focused on female residents. Although valuation literature on gender differences in WTP for urban public services overall has divergent findings, there were no statistical differences by gender for the WTP for public services similar to some of the AWIPM services, such as garbage collection, preventing illegal dumping, and collection of yard clippings (Dupont 2004, Alozie and McNamara 2010, Cameron et al. 2010).

Finally, our sample was relatively small, the response rate was limited by incomplete contact information, and the sample was chosen from homogeneous neighborhoods. These factors precluded our ability to detect potential effects of household characteristics such as a child in the home (Dupont 2004), county, income, and respondent's age and gender. Nevertheless, the sample was adequate to estimate mean WTP with a standard error of only 30% of the mean and the lower confidence bound on WTP gave a generous margin for additional spending if needed. Nevertheless, estimates of WTP should be extrapolated with caution.

In conclusion, using a CV method, this study indicates the value residents place on the benefits associated with a theoretical mosquito control program comparable to an AWIPM program. The results, suggesting a WTP about triple the existing budget, may inform policy makers in planning to control urban mosquito species. These conclusions apply only to a population that was considering the routine situation in which mosquitoes were primarily a nuisance and not disease vectors. Presumably, in the event of an outbreak of chikungunya or dengue, the population would be even more willing to pay for mosquito control.

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