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PUBLIC PERCEPTION OF MOSQUITO ANNOYANCE MEASURED BY A SURVEY AND SIMULTANEOUS MOSQUITO SAMPLING

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ABSTRACT. For randomly chosen residents of the Minneapolis–St. Paul, Minnesota, metropolitan area, survey responses, reported bites, and observed defensive behaviors (e.g., brushing, swatting) for a 5-min period in their yard were compared with simultaneous mosquito counts from a human-baited drop-net trap 6 m from the resident. When mosquitoes trapped, reported bites, or observed behaviors per 5 min were 3 or more, the majority of respondents described the mosquito levels as greater than "moderate" and anticipated reduced outdoor time and/or possible repellent use. At 25 or more mosquitoes trapped, 11 or more reported bites, or 16 or more observed behaviors per 5 min, response was "bad", with most people anticipating a major reduction in outdoor time (without repellent), "probably" or "definitely" planning to use repellent, and anticipating some outdoor time loss even if using repellent. Levels of less than 3 mosquitoes trapped per 5 min were related to moderate annoyance in 20–45% of the population. Individual response was highly variable, and the personal and environmental covariates measured did not account for more than half the variability.

INTRODUCTION

Part of the mission of the Minneapolis–St. Paul area Metropolitan Mosquito Control District (MMCD) is "to reduce annoyance levels of mosquitoes and gnats below that which interferes with outdoor activities". However, little information is available on what level of mosquito numbers, as measured by a standard technique, is considered annoying or affects activity outdoors.

Existing studies have evaluated mosquito impacts based on either attack rates (bites per unit time) or cumulative exposure (bites per night). The earliest study of attack rates was by Headlee (1932), who stated that at attack rates greater than one mosquito in 15 min "the density is sufficient to give the householder trouble", based on his previous experience. A survey by John et al. (1987) of residents of Jefferson County, Texas, found that the mosquito problem was considered "none" at a median of 2 (average 5.7) bites per hour per night, "mild" at 5 (average 7.7), and "severe" at 11 (average 11.5). Morris and Clanton (1988) found that residents of Sarasota and Polk counties, Florida, on average thought one attack per 30 min was between a "slight" and "moderate" mosquito problem (2.3 on a scale of 1 to 5), one attack per 12 min was "moderate", and one attack per minute was "bad" (4 on the same scale).

Studies using cumulative exposure show somewhat different results. Robinson and Atkins (1983) found that the median number of bites Virginia Beach residents said they would tolerate per night was 3 (average 8). Of those surveyed, 94% considered 10 bites per night a problem, 32% considered 4 bites per night a problem, and 13% considered one bite a problem. Sjogren et al. (1977[2]) reported the median number of bites Minneapolis–St. Paul residents said would force them indoors for the evening was 3. These results seem to show lower tolerance than Headlee (1932) and the other attack rate surveys, but both could apply at the same time (e.g., one attack or bite per 15 min up to a total of 3 bites per night).

Although the above survey results tend to agree, they report only people's perception of mosquito numbers, with no reference to actual counts. They also give little idea of the costs in outdoor time loss or repellent use associated with mosquito annoyance.

Two previous studies by the MMCD evaluated public response to mosquitoes where mosquito numbers were measured or controlled. A study by Genereux for the MMCD Environmental Impact Statement (Sjogren et al. 1977[2]) compared a phone survey of 1,920 households in 16 census tracts with collections from 5 dusk 5-min landing

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[2] Sjogren, R. D., J. P. Genereux and M. M. Genereux. 1977. Metropolitan Mosquito Control District final environmental impact statement—options for control to the year 2000. Metropolitan Mosquito Control District, St. Paul, MN.

counts from the same time period and tract. The average landing count (LC) explained less than half the variability in average percentage of outdoor time reduction (%R) using linear regression (%R = 14.64 + 2.26 [LC], $R^2 = 0.44$, $n = 16$), and the high intercept value implied that time would be reduced even if no mosquitoes were collected in landing counts. The average dollars ($S) spent on sprays and repellents per tract had a stronger relationship with landing counts ($S = 2.07 + 0.36 [LC], $R^2 = 0.79$). This study was done in a year when landing counts were low (highest night's average: 10.6, most under 1.5 per 5 min). The counts were done on an area-wide basis (5 per census tract) and averaged, resulting in few points for a robust regression analysis. Landing rate counts also have some weakness as a standard method because collector skill may influence the number of mosquitoes caught (Headlee 1932).

In 1982 and 1983, the MMCD sponsored a public perception survey (Sherman 1983[3]) in conjunction with a test of increased treatments. In 1982, the percentage of respondents "seriously" or "extremely" annoyed during the test week was significantly lower in the areas with increased treatments. In 1983, some of the areas receiving increased treatment were switched with those receiving standard treatment. The percent "seriously" or "extremely" annoyed in 1983 was not much lower in areas with increased treatment, and the response seemed to depend in part on the previous year's treatment (i.e., more or fewer mosquitoes than last year).

Morris and Clanton (1989) found significant correlations between CO_2 trap counts of mosquitoes, especially *Aedes* spp., and service requests in Polk County, Florida, but parameters of the relationships were not given.

The purpose of the study described below was to test whether residents' perceived annoyance levels and anticipated responses (reduced outdoor time, repellent use) were related to mosquito counts taken with a standard method at the same time and location. It improved on previous research by collecting concurrent paired mosquito and resident data and by testing effects of other factors on response. This approach also allowed estimation of the variability among residents' perceptions of annoyance.

[3] Sherman, R. E. 1983. Report on the 1983 Metropolitan Mosquito Control District special survey on mosquito problems. Hennepin County Office of Planning and Development, Minneapolis, MN.

MATERIALS AND METHODS

The study design compared responses of individuals from a 5-min period in their yard with mosquito trap counts at the same times and locations and tested the importance of environmental and personal factors. The human-baited drop-net trap (Rooker et al. 1994) was chosen for a standard mosquito collection method because it mimics public exposure and thus was most likely to be closely related to individual responses. Two other measures were taken for each individual: their perception of how many bites were received during the test time and observed frequency of defensive behavior (e.g., waving, swatting).

Choice of survey sample: Study participants were selected from throughout the 7-county Minneapolis–St. Paul metropolitan area included in the MMCD (*ca.* 3,300 mi.^{2} [8,500 km^2], population 2.2 million). Participants were limited to metropolitan residents over 18 years of age (one per household) living in single-family homes with a back yard at least 625 ft.^{2} (58 m^2). A nested design was used based on 1980 U.S. census tracts with over 100 acres of single-family housing. Fifty tracts were chosen at random, with proportional allocation from 15 strata set up based on population density and municipality. Within each tract, 2 quarter-sections were randomly chosen, and in each of these 2 one-block sized areas were selected (4 samples per census tract). Reverse directories were used for phone listings, and randomly selected households were phoned one night prior to sampling to solicit participation and set an appointment with a resident. Participation compliance was 50% (200/402 residents contacted). Sampling was conducted from June 20 to September 5, 1990.

Survey application and simultaneous mosquito collection: Residents were visited at a prearranged time between 1945 and 2200 h on a given evening. Staff members arriving at the house chose 2 locations in the yard about 6 m apart with similar ground cover, wind, light levels, and proximity to brush or trees and used a random method to assign the drop-net trap or resident to each location. The resident sat in a chair facing away from the trap and filled out the 1st page of the survey (questions on outdoor time) for 5 min, while one staff member served as bait in the trap and another observed weather and resident behavior. At the end of the 5-min test time, the resident filled out the 2nd part of the survey (questions on their perception of the mosquitoes during the previous 5 min), the trap net was dropped over the staff member, and the trapped mosquitoes were collected. If residents were particularly uncomfortable due to mosquitoes during the test time, they were allowed to go inside after 2 min and complete the survey.

Mosquito collection: The trap used for a standard collection technique was a human-baited drop-net trap, the Whole Person Bag Sampler (WPBS) (Rooker et al. 1994). During the 5-min baited time, the sides of the 1.5-m-diam cylindrical net were drawn up, allowing mosquitoes access to the staff person inside. At the end of the 5-min exposure time, the net sides were dropped rapidly, and all biting insects trapped were collected with a portable vacuum. Mosquitoes in the trap samples were counted and identified to species. Trap catch is known not to be significantly affected by the person baiting and collecting (Rooker et al. 1994); however, to minimize factors shown to affect mosquito attractiveness from other studies (Gjullin 1947), all collectors wore light tan shirts and did not use repellent.

Survey: The 1st page of the survey contained questions about a resident's typical outdoor activities and was to be filled out during the 5-min exposure time. The main purpose of this page was to give the resident something to do other than concentrate on mosquitoes during that time, and the questions did not include any references to mosquitoes. The questions did, however, collect useful information on the amount of time participants spent outdoors and at what hour they usually went indoors.

The 2nd page, to be filled out immediately following the 5-min exposure, asked for the resident's description of current mosquito levels (on a scale from "none" to "severe") and how long they would stay outdoors (of 2 h planned) if exposure continued. It also asked whether the individuals ever used repellent, whether they would use it now (if staying out), and how long they would anticipate staying out (of 2 h planned) if they did use repellent. The final question asked for an estimate of the number of bites received during the 5-min test time. Most of the questions were set up on a continuous scale with labeled ticks (similar to the axes in figures, below) to allow for direct comparison with mosquito numbers. Data for these questions were recorded by measuring the distance from the left edge of the scale to the point where the respondent's mark crossed the line. Pretesting was conducted on 17 volunteers.

Personal and environmental covariates: Staff members conducting the survey observed residents' clothing coverage (short or long sleeves, short or long trousers, socks, and shoes), apparent sex, and skin color (a factor in mosquito attraction according to Brown 1966). Temperature and relative humidity were measured using a battery-operated psychrometer at 30–60 cm above ground level between the resident and trap location. Light levels were measured at the same location using a photographic light meter, and wind was described using the Beaufort scale. Age, time normally spent outdoors, and perceived tolerance to mosquitoes were gathered from the survey form. Median income for the census tract (1980 U.S. census data) was used as an estimate of income. Census tracts were classified as urban (35 tracts), suburban (10 tracts), or rural (5 tracts) based on 1980 population density.

Behavior observations: Participants' defensive behavior during the 5-min exposure time was observed unobtrusively by the staff person recording covariates. Each occurrence of 4 types of behaviors (scratching or rubbing, waving or brushing, slapping or swatting, other) was counted.

Analysis methods: Linear and nonlinear regression analysis was done using the statistical packages SYSTAT (Wilkinson 1989) and Multreg (Weisberg 1981). Based on residual analyses, the values of trap counts, self-reported bite counts, behavior counts, and light (lux) were converted to $\ln(x + 1)$ before final analysis. For comparisons such as trap count vs. reported bites, where both variables were measured with error, Model II reduced major axis regression (nonlinear) (Wilkinson 1989) was used. For some comparisons, response was analyzed by mosquito density categories, which were constructed such that each category had no less than 18 responses (most had more than 20).

For most of the analyses, the distribution of variability and relationship between the variables was such that linear regression was not a useful estimator of central tendency. A data-smoothing procedure called "robust locally weighted regression" (or "lowess") was used to show the middle of the distribution of y as it changed with x (Cleveland 1985), similar to a median. The y value fitted for a given x using lowess smoothing depends not only on the actual y values at x but also on neighboring values. The range and influence of neighboring values used were set by the "tension" parameter. Lowess is particularly useful when the functional form describing the relationship between y and x is unknown (Cleveland 1985, Wilkinson 1989).

For assessing the importance of personal and environmental covariates, multiple regression with the Multreg "screen" command was used. Instead of using a stepwise method, this command uses the "leaps and bounds" algorithm (Weisberg 1981, 1985) to select combinations of variables that result in the best models. The criterion for best models was Mallows' Cp, an estimate of the error of prediction based on the residual sum of squares penalized for additional

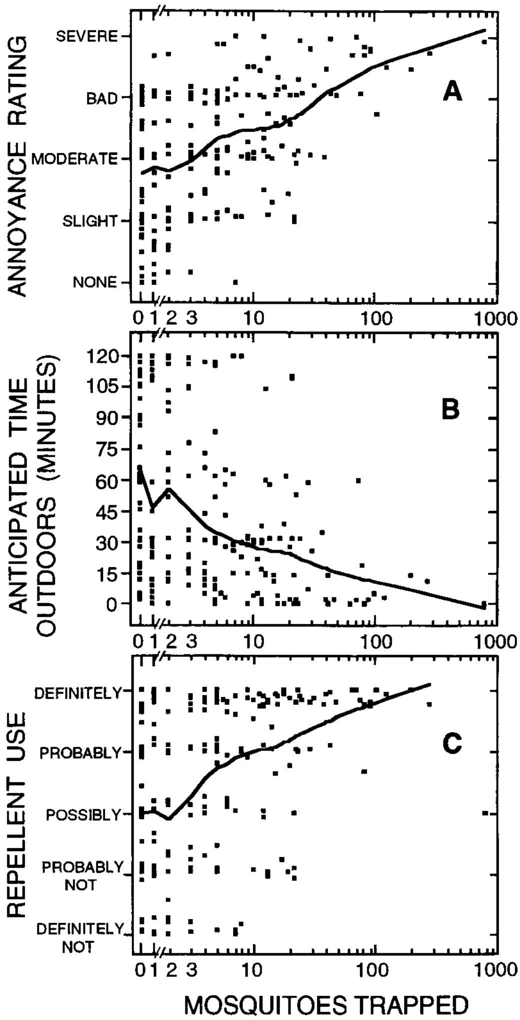

Fig. 1. A. Annoyance rating vs. number of mosquitoes trapped per 5 min, with lowess curve (tension = 0.30). B. Anticipated time outdoors (of 120 min planned) vs. number of mosquitoes trapped per 5 min, with lowess curve (tension = 0.33). C. Anticipated repellent use vs. number of mosquitoes trapped per 5 min, with lowess curve (tension = 0.33). The value at mosquitoes = 796 was not included in the lowess calculation for repellent use.

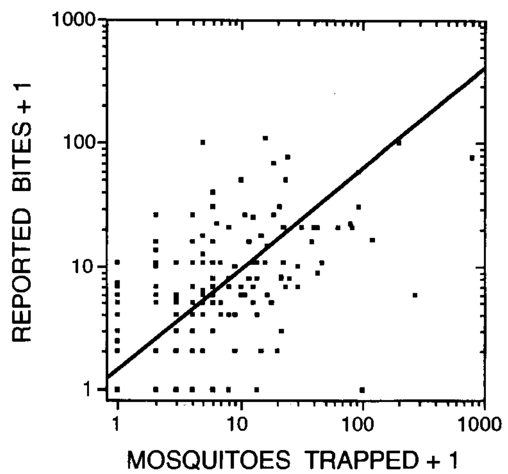

Fig. 2. Reported bites + 1 vs. mosquitoes trapped + 1, with model II regression line (both variables measured with error). Both variables are shown on log scale, adjusted (+1) to show 0 values. Equations for line given in text.

variables (related to adjusted R^2; Weisberg 1981, 1985). The "screen" command tested all possible regression models using the covariates and reported the 5 best sets of covariates giving the smallest error of prediction for a given response.

RESULTS

Sample characteristics: The sample racial distribution was 97% white, 1% black, and 2% other, almost identical to the population (1980 census), but the proportion of people of color was insufficient to use skin color as a covariate. The distribution of ages in the sample (3% 19–24, 17% 25–34, 50% 35–54, 16% 55–64, 13% 64–90) had a higher proportion of 35–54 year olds and fewer under 35 than expected, probably due to the single-family home restriction in sample selection. Although we attempted to randomize selection of individuals within a household, we were not always able to do so. As a result, the sample was 37% female and 63% male, which was significantly different from the population.

The sample represented only people who were willing to sit in their yard for 5 min; the 50% compliance ratio from phone contacts might suggest that, if any bias was present, it was toward people who were more tolerant of mosquitoes. However, when asked, "Compared to other people you know, how would you describe your tolerance for mosquitoes?", responses ranged from very low to high on a scale of "very low" to "very high", with a median of moderate. Men's self-report of tolerance was significantly higher than women's (t-test, $P < 0.01$). Self-reported tolerance did not vary with age group or urban/suburban/rural location.

Mosquito collections: The most abundant mosquito species collected was *Aedes vexans* (Meigen) (74% of the total), followed by *Ae. cinereus* Meigen (11%) and *Ae. sticticus* (Meigen) (5%). Because these 3 species accounted for 90% of the mosquitoes collected, analysis was done on total mosquito numbers and not separated by species. Mean 5-min trap count each week was between 3 and 10 mosquitoes for most weeks sampled but ranged as high as 60. The highest trap count recorded was 796 mosquitoes in 5 min.

Trap counts vs. survey results: Described annoyance at trap counts of 2 or fewer mosquitoes per 5 min was just under "moderate" (lowess curve, Fig. 1A), but individual responses were highly variable, ranging from "none" to "bad". At higher numbers of mosquitoes trapped, annoyance was higher and had less variability. For trap counts from 3 to 30, the response curve was between "moderate" and "bad" with individual responses ranging from "slight" to "severe". All respondents exposed to more than 40 mosquitoes per 5 min described conditions as "bad" or "severe".

Anticipated time outdoors (of 2 h planned) also showed high variance at low trap counts (Fig. 1B) and suggested a divergence between those who would go indoors after less than 60 min and those who would stay outdoors over 90 min (e.g., bimodal distribution at trap count of one). Time outdoors decreased rapidly between counts of 2 and 8, and at trap counts of 9 or higher most people anticipated remaining outdoors 30 min or less.

People's anticipated repellent use was similar to described annoyance (Fig. 1C). At trap counts of 2 or less, responses centered on "possibly". Between 5 and 20, responses centered on "probably", and of those experiencing counts above 20, almost all would "definitely" have used repellent.

Self-reported bite count and observed behaviors: Respondents' reported bites received during the 5-min test time increased with increasing trap count but were not as closely related as might be expected ($\ln[\text{bites} + 1] = 0.29 + 0.87 * \ln[\text{trap count} + 1]$; Fig. 2). Observed defensive behaviors also increased with trap count ($\ln[\text{behavior count} + 1] = 0.38 + 0.89 * \ln[\text{trap count} + 1]$) and was more variable at low counts and less at high counts than was reported bites. Behaviors increased with increasing reported bite counts ($\ln[\text{behavior count} + 1] = 0.086 + 1.02 * \ln[\text{bites} + 1]$) and had a pattern of variability similar to bites vs. trap counts.

The relationship between reported bites and annoyance (Fig. 3A) was similar to that of mosquitoes trapped but with less variability at low counts. Bite counts of 0–1 had an annoyance response of "slight". Annoyance was "moderate" at 3 reported bites per 5 min and "bad" at 20 reported bites. Anticipated time outdoors was approximately 80 min at reported bites of 2 or less, dropping to 30 min at 6 bites and 15 min at about 15 bites (Fig. 3B). Anticipated repellent use was "probably not" at 0 bites, going up to "possibly" at 2 bites and "probably" at 7 bites per 5 min (Fig. 3C). The relationships between observed behavior count and annoyance, anticipated time outdoors, and anticipated repellent use were very similar to those shown for reported bites.

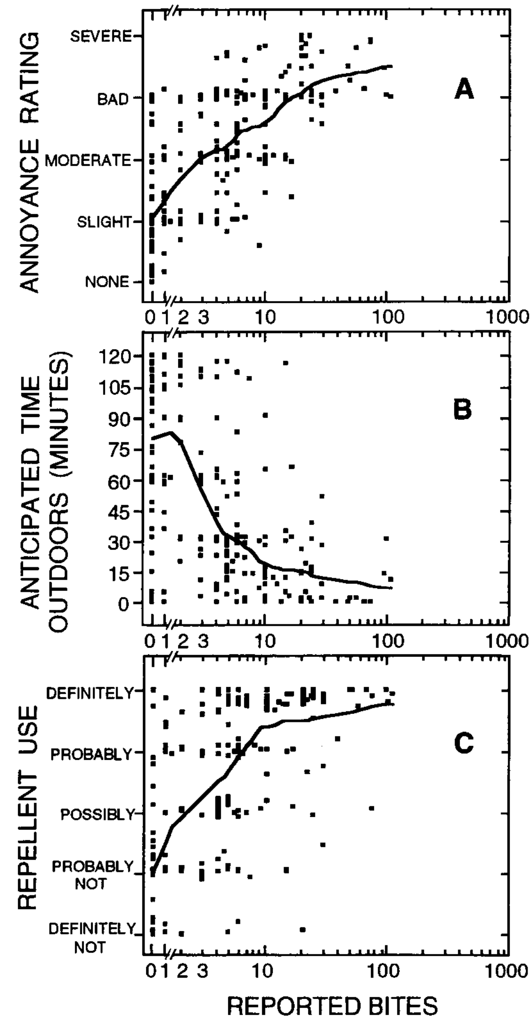

Fig. 3. A. Annoyance rating vs. reported bites per 5 min, with lowess curve (tension = 0.30). B. Anticipated time outdoors (of 120 min planned) vs. reported bites per 5 min, with lowess curve (tension = 0.33). C. Anticipated repellent use vs. reported bites, with lowess curve (tension = 0.33).

Influence of other covariates: The personal and environmental covariates measured did not explain much more of the variability in the responses than did mosquito, bite, or behavior counts alone. The best multivariate linear models selected by the "screen" algorithm for the

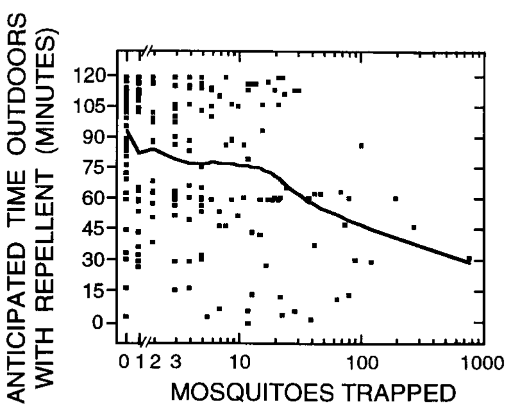

Fig. 4. Anticipated time outdoors (of 120 min planned) if using repellent vs. number of mosquitoes trapped per 5 min, with lowess curve (tension = 0.33).

regression of annoyance rating, anticipated time out, repellent use, reported bites, or observed behavior on trap counts and added covariates had R^2 values of 0.25–0.41, compared with R^2 values of 0.16–0.28 without the added covariates. The best models for annoyance rating or observed behavior based on reported bites and added covariates had R^2 values of 0.49 and 0.57, respectively, compared with 0.44 and 0.47 without covariates.

Despite their low overall impact, many of the personal and environmental covariates contributed significantly to the regressions (i.e., had slopes significantly different from 0, as indicated by their regression P-value). Another indication of the reliability of a covariate's contribution was the frequency of its presence in the 5 best models selected by the "screen" algorithm for a given response. Because many of the covariates were correlated with each other, the regression P-value differed among the 5 best models depending on which other variables were included in the model.

Wind was the most consistently significant covariate. It was almost always present in the best multivariate linear models. Increased wind at a given trap count was related to decreased annoyance or likelihood of repellent use and increased time remaining outdoors (P = 0.11–0.00001, depending on which other variables were included in the model). Self-described tolerance also was frequently present in the best models, but it did not usually have a very large influence. Higher tolerance was significantly related to a lower likelihood of using repellent (P = 0.003). Sex was significantly related to time remaining outdoors, with men staying out 10–20 min longer than women (P values of 0.09–0.0001). Men were also somewhat less likely to use repellent (P = 0.05–0.004) but reported more bites than women at a given trap count (P = 0.01).

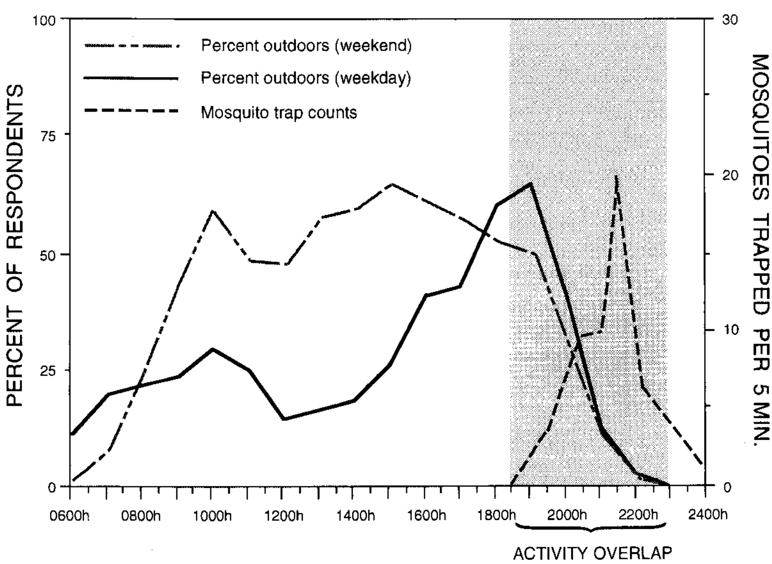

Fig. 5. Frequency distribution of number of positive responses for time currently spent outdoors (page 1 of survey) on weekdays or weekends, by time of day, along with mean WPBS trap count of mosquitoes (per 5-min exposure) for samples taken in June and July 1990 and in previous studies. Shaded area represents activity overlap for humans and mosquitoes at this time of year.

Table 1. Association of anticipated impacts with mosquito annoyance descriptor terms.

Annoyance descriptor	Time remaining out of 120 min planned, without repellent	Likely repellent use	Time remaining out of 120 min planned, with repellent
None	>90 min	no	>90 min
Slight	90 min	possibly	>90 min
Moderate	≤60 min	probably	>60 min
Bad	<30 min	definitely	60 min
Severe	<15 min	definitely	<60 min

People wearing more clothing (i.e., long sleeves, long trousers, socks, and shoes) had somewhat lower annoyance response for a given trap count (P = 0.09–0.04, depending on other variables present in model). They also expected to remain outdoors longer (P = 0.10), were less likely to have bites or show defensive behavior (P = 0.006 for each), and were more likely to use repellent (P = 0.01–0.005). Higher census tract average income was somewhat related to increased time remaining outdoors (P = 0.11–0.003). Higher income was significantly related to lower repellent use (P = 0.01–0.0004), but the influence was small. Higher temperatures were related to a slight increase in repellent use (P = 0.14–0.01) and possibly to increased annoyance (P = 0.14, selected in best model). Higher light levels were related to a small but significant reduction in reported bite counts or behavior counts for a given trap count (P = 0.01–0.0008). Humidity, location (urban/suburban/rural), and age were very seldom in the top 5 models and did not appear to be strong predictors of any of the responses examined.

Effect of repellent use: Respondents' anticipated time remaining outdoors, of 2 h planned, was an average of 31 min longer with repellent than without repellent (186 df, P = 0.0001). Anticipated time outdoors with repellent showed less influence of mosquito numbers (Fig. 4A) than did time outdoors without repellent (Fig. 1B). However, time outdoors with repellent decreased to less than 1 h (of 2 h planned) at mosquito trap counts over 25 per 5 min. Time outdoors with repellent showed a similar relationship to reported bites (Fig. 4B), declining to less than 1 h (of 2 h planned) at reported bite counts over 11 per 5 min. When asked, "Do you ever use repellent?", 19% of those surveyed responded "No".

Outdoor time: The average time respondents reported going indoors was 1947 h, compared with an average time of 2044 h if there were no mosquitoes (mean difference 57 min, P = 0.0001, paired t-test). Anticipated time if no mosquitoes were present was generally between 2000 and 2200 h and did not show a strong relationship with sex, age, or urban/rural location.

Results from the 1st page of the survey showed the frequency of residents' typical outdoor activity (Fig. 5) peaked on week nights at 1900 h and declined steadily to near 0 at 2200 h. Data from this and previous unpublished studies done at the MMCD showed mosquito activity in early August (sunset 2030 h) began around 1900 h and peaked around 2130 h. Both people and mosquitoes are active at this time of year between 1830 and 2200 h, the "activity overlap".

DISCUSSION

Variability at low counts: The variability in public response at low trap count levels could be a function of the short trapping time. John et al. (1987) and Morris and Clanton (1988) both found that a rate equivalent to 0.4 bite per 5 min (5/h or 1/12 min, respectively) was described as a moderate problem. Headlee's 1 in 15 is a rate equivalent to 0.33 per 5 min. This suggests that people's sensitivity may be at a lower level of mosquitoes than we were able to detect reliably with a 5-min experimental period. Respondents might also have been reacting to exposure before or after the 5-min test period. The difference between trap count and the concurrent reported bites or observed behaviors could reflect a difference in mosquito abundance at the 2 locations in the yard but probably is due to the influence of individual perception on both bite counts or behaviors and survey responses.

Defining acceptable impacts: A comparison of annoyance descriptor response ("none" to "severe") with other measures (time remaining out, likelihood of repellent use, and time remaining out if repellent used) was used to give an idea of people's perception of acceptable mosquito levels (Table 1). Ideal control would keep mosquito levels low enough that most people would consider them "none" or "slight". Keeping mosquito levels low enough that most people consider them no worse than "moderate" would probably be acceptable, especially for those who

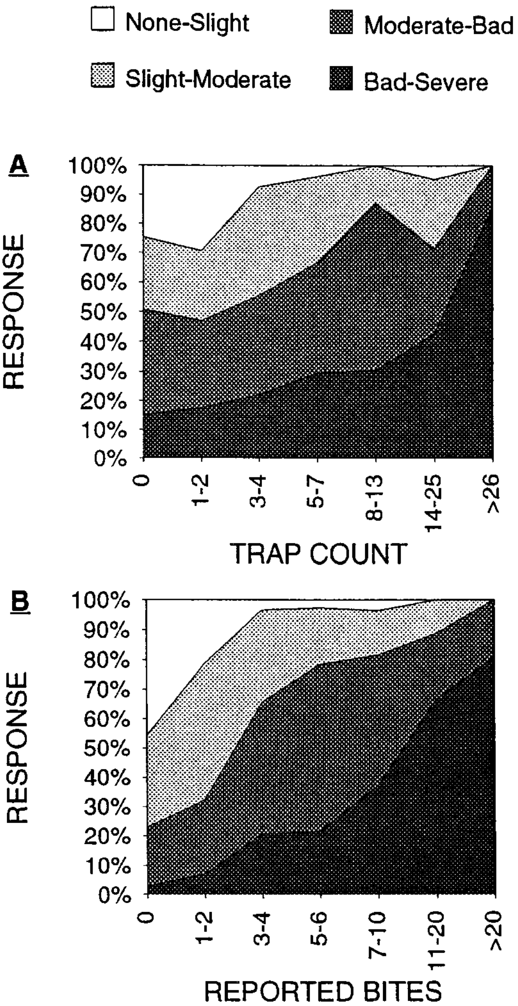

Fig. 6. A. Percent response in annoyance rating by range (none–slight, slight–moderate, moderate–bad, and bad–severe) vs. drop-net trap mosquito count category. Vertical axis is cumulative; for example, at 0 mosquitoes trapped, "bad" to "severe" was 15% of the total, "moderate" to "bad" was 36%, "slight" to "moderate" was 24% of the total, and "none" to "slight" made up the final 25%. B. Percent response in annoyance rating by range (none–slight, slight–moderate, moderate–bad, and bad–severe) vs. reported bite count category.

use repellent. The minimum control expected would be to keep mosquito levels no more than what most people consider "bad". At "severe", people anticipated impacts that would overwhelm personal defensive actions such as repellent use.

By our measurements, reported annoyance was greater than "moderate" at trap counts (Fig. 1A), reported bite counts (Fig. 3A), or observed behavior counts of 3 or more per 5 min. Response was in the "bad" range at 25 or more trapped (Fig. 1A), 11 or more reported bites (Fig. 3A), or 16 or more defensive behaviors per 5 min. At a point exposure of 2 mosquitoes trapped per 5 min, about half of those surveyed would describe the mosquito level as moderate, slight, or none (Fig. 6A) and would be likely to use repellent. At 2 reported bites per 5 min, about ⅔ of those surveyed would describe the mosquito level as moderate, slight, or none (Fig. 6B), would be likely to use repellent, and, if planning to stay out 2 h, would last over 1 h without repellent or almost the full 2 h with repellent. Over ⅔ of those surveyed described levels as "severe" at 26 or more mosquitoes trapped or 11 or more reported bites per 5 min.

The relationship between percentage of time reduction and 5-min landing count described for the MMCD in 1977 (Sjogren et al. 1977[2]) predicted only a 20% reduction in outdoor time at 3 landings per 5 min and a 50% reduction at 15.6 landings per 5 min. This difference may be related to different mosquito population levels present in the years the studies were done or to the form of the questions (i.e., "% time" [1977] rather than "time of 2 hours planned" [1990]).

The decrease in annoyance per decrease in mosquito count was greater at lower mosquito populations than at higher mosquito populations. However, even at high mosquito populations a decrease could bring the population to the point where most people can have relatively little impact if they use repellent. In addition, if more mosquitoes are active earlier in the day when populations are high, the activity overlap would be larger and overall public impact would be greater than is implied by the relationships shown in this study. The timing and duration of mosquito exposure are important factors in annoyance that should be addressed in future research.

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