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A WHOLE-PERSON SAMPLER FOR ASSESSING NUMBERS OF HOST-SEEKING ADULT MOSQUITOES

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ABSTRACT. The whole-person bag sampler (WPBS) is a human-baited drop-net mosquito trap for evaluating an individual's exposure to nuisance mosquitoes. A diagram of WPBS construction is given, with results from field tests. Trap operator exposures of 2, 4, and 8 min did not result in a corresponding increase in mosquitoes caught in the WPBS, although simultaneous captures using a sweep net or Nasci aspirator increased with the sample duration. The person baiting and operating the trap did not have a significant effect on number of mosquitoes captured. Taxonomic diversity of adult mosquitoes collected with WPBS and CO_2-baited traps was similar, with *Aedes vexans* predominant in the study areas.

A common method to assess mosquito numbers is to capture adult mosquitoes associated with human hosts. However, problems with collector-induced variability led earlier workers to develop mechanized trapping methods using light or CO_2 as attractants (Headlee 1932, Mulhern 1942). Although such traps eliminate collector effect, captures may not reflect the numbers and species of mosquitoes that are normally attracted to humans (Slaff et al. 1983). For studies comparing mosquito numbers with human perceptions of annoyance (Read et al. 1994), standardized human-baited collections were needed. The drop-net trap design of Klock and Bidlingmayer (1953) provided a method that minimized effect of collector skill. We developed a drop-net trap, the whole-person bag sampler (WPBS), which was an improvement over the previous design by being free-standing, having a mechanical system for rapidly raising or lowering the net, and having removable sections for ease of transport.

The objectives of this study were to test the WPBS and compare some aspects of its operation with other common sampling methods. We evaluated the effects of duration of collector exposure and of different people in the trap on numbers of mosquitoes collected, and compared species composition of samples.

The WPBS is a cylindrical drop-net trap with a sampling volume of approximately 4 m^3 (Fig. 1). A 1.5-m-diam spoked top frame is supported by a detachable 2.1-m center pole with a tripod base. A reel and pulley system allows the operator to easily raise and quickly lower the net during sampling. Sampling begins when the operator raises the net and stands inside the trap. At the end of a defined exposure period, the reel is unlocked, allowing the weighted bottom hoop to drop and enclose the operator and associated mosquitoes within the net. Trapped specimens are collected with a modified battery-operated vacuum cleaner. If needed, a light source is used to find specimens in the trap. For transporting, the canopy can be partially separated from the center pole and tripod. One person can unload and set up the trap in 5 min. Retail cost of components is about U.S. $130. A complete parts list and construction guide is available from the Metropolitan Mosquito Control District.

The effect of sample duration on the number of mosquitoes caught was tested in June 1989. Collection methods were 1) a standing person in a WPBS with net raised for the sample time, dropping net at the end of the time, 2) a standing person sweeping continuously all around him- or herself for the sample time using a 30.5-cm-diam sweep net, and 3) a person with a 35-cm-diam aspirator (Nasci 1981) walking slowly for the sample time in a spiral starting at the designated location and moving the aspirator opening up and down approximately 1 m. Sampling was done on 3 nights, each night at a different site in the Minneapolis–St. Paul area. At each site, 3 locations at least 20 m apart with similar canopy, light level, and distance to vegetation were chosen and were randomly assigned a method and collector for the evening. The 2-h period after sunset was divided into 3 time blocks, each containing sampling periods of 2, 4, and 8 min (in random order) with 5-min non-sampling periods between samples, for a total of 9 samples per method per evening. Analysis was done using the General Linear Model procedure in SYSTAT (Wilkinson 1989) with the categorical variables "day" and "time" as blocking factors and the continuous variable "duration" as treatment.

The effect of different people baiting and operating the WPBS was tested in May and June 1990 using a replicated Latin square design. Test

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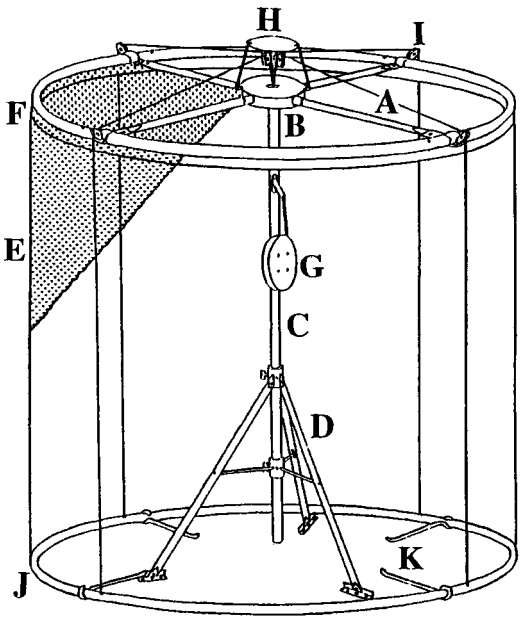

Fig. 1. Whole-person bag sampler (WPBS). Spoked top frame consists of 4 70.2-cm sections (A) of 1.3-cm-diam metal conduit radiating from a center junction box (B). A 15-cm length of 1.3-cm-diam conduit connected to the bottom of the junction box fits in the top of the center pole such that the top frame is held on by gravity and is easily removed from the base. The base is a 213-cm-high center pole of 1.9-cm-diam conduit (C) supported by a 91-cm-high metal tripod (TV antenna type) (D). "No-see-um" netting (E) is supported by a framework of 152-cm-diam hoops (F) made from plastic "hula" hoops. Netting stress points are reinforced with muslin. The 17-cm wooden reel (G) is mounted on a bearing plate and bolted to center pole. Dacron tow line (68-kg test) is run from reel through angled nylon hose adapter tapped into hole on center pole. The line is run inside center pole up through junction box to swivel eye pulleys (H), which are riveted to suspended base plate above the junction box. The line is strung through fixed eye pulleys (I) at the distal end of each spoke and down to the weighted bottom hoop (J). Net gatherers (K) of heavy wire covered with plastic tubing collect side netting when net is raised.

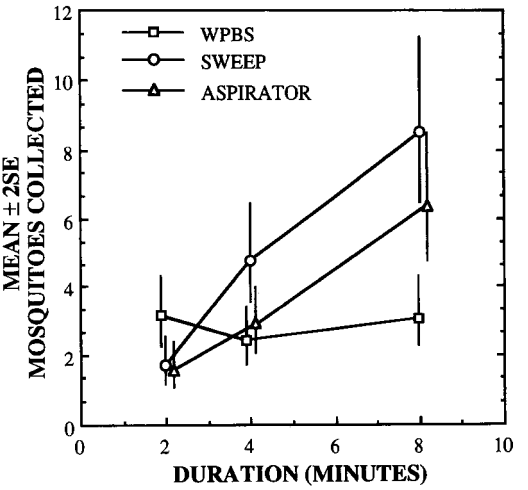

Fig. 2. Mean number of mosquitoes collected (all species) ± 2 SE vs. duration of collection time (aspirator, sweep net) or exposure time (WPBS).

sites were in the Minneapolis–St. Paul area in 2 suburban wooded housing developments and adjoining open fields. Two Latin squares were run for 2 nights in Lakeville and for one night in East Bethel for a total of 6 squares. Each square consisted of 5 locations, 5 times, and 5 people. Locations were chosen at random at least 30 m apart within the available sampling area. The 2-min WPBS samples were done at 30-min intervals, with the 1st at 1 h before sunset and the 5th at 1 h after sunset. All participants wore tan shirts and long trousers. Trap locations and operators were generally different between squares, but there was some repetition of each. Results were analyzed as a replicated Latin square design with people and locations nested within squares (Montgomery 1984). Calculations for analysis of variance and coefficients for estimated effects were done using MacAnova (Oehlert 1990).

Carbon dioxide-baited traps were used concurrently with the person effect experiments to compare species composition of samples. Traps were CDC miniature light traps (with light removed) baited with 2.3 kg of dry ice pellets and hung 1.5 m off the ground. A trap was placed *ca.* 30 m away from each WPBS location, in a direction perpendicular to the wind to minimize attractant interference. Two samples were collected from each trap: one for dusk, run continuously from 1 h before sunset to 1 h after sunset (the period when WPBS samples were taken), and one overnight, from 1 h after sunset to about 0900 h the following morning.

Results of the sample duration trial showed that the number of mosquitoes (all species) caught in the WPBS was not related to the length of collector exposure period (ANOVA, $F_{1,21} = 0.011$, $P = 0.92$). In contrast, the number of mosquitoes caught with the sweep net or aspirator increased with sample duration (sweep: $F_{1,21} = 16.40$, $P = 0.001$; aspirator: $F_{1,21} = 17.68$, $P < 0.001$). All analyses were on data transformed as ln(count + 1) to stabilize the variance. Means and upper and lower 95% confidence limits based on the pooled standard error are shown in Fig. 2 (all calculated in transformed scale and back-transformed for display).

Table 1. Species and relative abundance of adult mosquitoes collected with the WPBS traps (2-min exposure) and CO_2 traps (run 2 h). Numbers given are counts of each species as a percentage of total catch by method except for the last 2 rows of the table.

Species	Lakeville		East Bethel	
	WPBS	CO_2	WPBS	CO_2
Aedes vexans	48.4	70.0	67.9	89.2
Aedes cinereus	32.3	9.8	18.0	2.6
Aedes (*communis* group)	7.8	5.6	7.4	3.2
Aedes (*stimulans* group)	9.5	9.1	1.9	0.7
Aedes dorsalis	0	0	0	<0.1
Aedes spp.	0.2	3.3	0.3	0.4
Culiseta inornata	0.7	1.8	1.3	2.3
Culiseta spp.	0	0	0	<0.1
Anopheles walkeri	0	0	2.1	1.0
Anopheles punctipennis	0.1	0.1	0.3	0.4
Anopheles spp.	0.1	<0.1	0	0.2
Culex restuans	0.3	<0.1	0.1	<0.1
Culex tarsalis	0	<0.1	0	<0.1
Culex spp.	0	0.1	0	<0.1
Males (all spp.)	0.6	0.2	0.8	0.1
Unidentifiable	0.1	<0.1	0	0
Mean no. per sample	15.8	147.3	70.3	1,322.8
Samples (*n*)	100	20	50	9

Analysis of variance for person effect showed significant differences ($P < 0.01$) among squares ($F_{5,92} = 35.0$), among times ($F_{4,92} = 9.4$) and among locations within squares ($F_{24,92} = 2.99$) but no significant difference among people within squares ($F_{24,92} = 1.11$, $P = 0.35$). All analyses were on data transformed as ln(count + 1) to stabilize the variance. Analysis coefficients for only 2 of the 17 people tested were significantly different ($P > 0.05$) from zero. There was no consistent difference between coefficients by gender.

Both the WPBS and dusk CO_2 samples contained a broad range of mosquito taxa (Table 1). The CO_2 traps at both sites collected more taxa than WPBS traps, probably due to their longer running time and higher total collection. However, the CO_2 traps collected a higher percentage of *Aedes vexans* (Meigen) and fewer *Ae. cinereus* Meigen than did the WPBS. Results for overnight CO_2 samples were similar in taxa and numbers to the dusk samples.

For moderate cost and effort, the WPBS provides a method for evaluating human exposure to mosquitoes that is not affected by the person using the sampler. This result is in contrast to studies of landing or probing, where differences between people have been demonstrated (Maibach et al. 1966). It is possible that people are very similar in long- or moderate-range attractiveness to mosquitoes, up to the diameter included in the WPBS, and differ only in short-range or landing cues. The WPBS also minimizes the effect of collector skill. Although the WPBS can be used without regard to the person making the collection, we recommend minimizing differences in factors that are easy to control and have been shown to affect attraction, such as clothing color (Gjullin 1947) or repellent use.

The effect of sample duration differed between the WPBS and other methods of adult mosquito collection compared. Exposure period had no apparent effect on WPBS catch, which suggests that mosquitoes are attracted to a host at a constant rate but also leave at that rate, resulting in equilibrium rather than continuous increase. Thus this method estimates human exposure at a given time but does not evaluate cumulative human–mosquito encounters.

In conclusion, the WPBS combines many of the standardizing effects of mechanical traps with the relevance of a human bait for estimating public exposure to mosquitoes. The WPBS has been used to compare people's mosquito exposure with their response to an opinion survey (Read et al. 1994). Further research is planned to compare the WPBS with simpler, less expensive sampling methods.

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ing development and testing of the WPBS. Many thanks also to the numerous field staff who played an essential role in our sampling.

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