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The Centers for Disease Control and Prevention Resting Trap: A Novel Device for Collecting Resting Mosquitoes

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Abstract

Commercially available wood-fiber pots used to collect resting mosquitoes were modified to improve sampling efficiency. The modified traps, called the Centers for Disease Control and Prevention resting traps, collected 16.0 and 5.2 times more adult *Culex pipiens* and *Cx. tarsalis* than the conventional wood-fiber pots. The resting trap increases the mean number of resting mosquitoes collected per trap-night and is useful for collecting blood-engorged mosquitoes.

Keywords

Resting mosquitoes; *Culex pipiens*; *Culex tarsalis*; resting trap

Most mosquito species are typically nocturnal or crepuscular, and remain relatively inactive during daylight hours. Samples of these resting mosquitoes provide effective estimates of mosquito population densities. Similarly, resting mosquito collections provide robust samples of blood-engorged mosquitoes. Tree cavities (Burkett-Cadena et al. 2008), animal burrows (Kay 1983), root masses (Mullen 1971), dense vegetation (Kay 1983), and caves are examples of natural daytime resting places for mosquitoes. Man-made structures such as barns, culverts, and basements, which provide dark, moist, and cool environments, also accommodate resting mosquitoes (Crans 1989). Researchers have taken advantage of the resting behavior of mosquitoes by sampling with artificial structures such as nail kegs (Burbutis and Jobbins 1958), wooden boxes (Gusciora 1971), walk-in red boxes (Meyer 1985), plastic trash cans (Burkett-Cadena et al. 2008), and wood-fiber pots (Komar et al. 1995).

Vector control and public health surveillance programs rarely collect resting mosquitoes, for several reasons. First, resting collections capture adult mosquitoes from a broad range of physiological states (i.e., host-seeking, blood-engorged, gravid, postovipositional) and thus are not useful for calculating vector indices, which are derived from collections of host-seeking female mosquitoes only (Gujral et al. 2007). Second, resting traps predominantly attract mosquito vectors in the genera *Culex*, *Culiseta*, and *Anopheles* (Goodwin 1942, Meyer 1985, Komar et al. 1995, Burkett-Cadena etal. 2008), but are ineffective for sampling many genera of nuisance and vector mosquitoes such as *Coquilletidia*, *Psorophora*, and *Aedes* (Gusciora 1971). However, resting collections offer the most efficient source of blood-engorged mosquitoes needed for several research applications, suchasvector and arbovirus ecology studies.

In order to enhance the collection of resting mosquitoes, a novel trap design was devised to combine the advantages of the wood-fiber pot (e.g., low cost and portability) with those of conventional, suction-type traps (few escapees, larger samples). Traditionally, collections from these pots are made daily by aspirating resting mosquitoes from the interior walls of the pots using either a handheld aspirator or a backpack aspirator. However, slight movements can startle resting mosquitoes before they can be aspirated, and changing environmental conditions such as temperature, humidity, and wind can cause mosquitoes to abandon their resting places. To address these problems, we modified the wood-fiber pot to improve mosquito collection efficacy by adding a suction device. We hypothesized that mosquitoes attracted to the pots would be aspirated into the collection nets before they alight on the internal walls, thus eliminating abandonment of the pot in favor of more suitable resting sites and the possibility of escape. The new design is termed the Centers for Disease Control and Prevention (CDC) resting trap.

We fabricated the novel CDC resting traps by cutting a 9-cm-diam hole in the bottom panel of a 30 × 30 × 30-cm wood-fiber pot (Western Pulp Products, Corvallis, OR) painted flat black on the interior surfaces. A 30-cm-long, 8.25-cm-diam polyvinyl chloride (PVC) tube containing a motorized fan (such as that used in the CDC gravid trap) (Hausherr's Machine Works, Toms River, NJ) was fitted into the opening. Wooden braces hold the PVC tube in position. A collection net was placed over the exhaust end of the PVC tube (Fig. 1). The motorized fan on the CDC resting trap can operate continuously for at least 3 days on 4 D-cell batteries.

We compared the efficacy of the CDC resting trap to wood-fiber pots (also painted flat black on interior surfaces) at 4 study sites in northern Colorado during August and September, 2008. Each of the sites was near a communal bird roost. In addition, we collected host-seeking mosquitoes with CO_2-baited CDC light traps to assess mosquito community composition. At each site, 30 to 50 wood-fiber pots were set and collections were made using a backpack aspirator (John W. Hock Company, Gainesville, FL) once per day. Four to 10 CDC resting traps were deployed at each site concurrently in similar microhabitats and collection nets were picked up daily. To evaluate possible differences in species-specific catch rates by trap type, we estimated the trapping success ratios using a mixed-effect Poisson regression model, adjusting for fixed species and random site and date-within-site effects; the number of trap-nights was incorporated as an offset, so that this model, in effect, compared expected counts per trap-night. Model selection was made using the likelihood ratio test (LRT) to test significance of fixed effects and the restricted LRT (RLRT) to evaluate random effects. Wald 95% confidence intervals (CI) were computed from the model fits and adjustment for multiple comparisons was made using Sidak's method. Residual analyses were used to evaluate model assumptions. To model the proportion of the mosquitoes that were engorged, we used mixed-effects logistic regression, where we used the same strategy as described above. The software Spotfire S+ version 8.1 (TIBCO Software, Inc., Palo Alto, CA) was used for analysis.

A total of 11 species of mosquitoes were collected. (Table 1). The wood-fiber pots and the CDC resting traps collected mostly *Culex* species in a greater proportion of engorged mosquitoes than the light traps (22.2% engorged from resting traps versus 1.4% from light

traps). In evaluating the expected numbers of mosquitoes collected per trap-night, the best-fitting model contained fixed effects for species, trap type, and their interaction, along with random effects for site and date-within-site. Species × trap type interaction (LRT P-value < 0.001), and random effects for date-within-site (RLRT P-value < 0.001) were retained. Residual analyses supported model assumptions.

Accounting for the random site and date effects, the novel CDC resting trap collected 16.0-fold (95% CI 6.3–40.7) as many female *Culex pipiens* L. and 5.2-fold (95% CI 3.5–7.5) as many female *Cx. tarsalis* Coq. per trap-night as the wood-fiber pots.

In the model for the proportion of mosquitoes that were engorged, the interaction of species and trap type was nonsignificant (LRT $P = 0.33$), while both main effects were significant (LRT $P < 0.01$). The comparison of trapping method averaging over species was significant, with an odds ratio for the CDC resting trap compared to the fiber pot of 3.6 (95% CI 2.1–6.3), indicating that the odds of the CDC resting trap collecting an engorged mosquito was nearly 4 times that of the wood-fiber pots.

The objective of this investigation was to improve upon an already effective method of collecting resting female *Culex* spp. By modifying wood-fiber pots, we were able to increase our collections by about an order of magnitude for both species of *Culex* targeted. Wood-fiber pots and CDC resting traps collected engorged mosquitoes in much greater proportions than CDC light traps, as expected. However, the percentages of engorged *Cx. tarsalis* and *Cx. pipiens* collected from fiber pots and resting traps did not differ significantly.

Resting collections in general are far superior to other types of collections for acquiring blood-engorged female mosquitoes. Collecting blooded female mosquitoes is a valuable tool for researchers evaluating host preferences of mosquitoes and pathogen transmission dynamics, and for mosquito control personnel interested in monitoring human biting rates among local mosquito populations. Modern polymerase chain reaction technology can now identify the blood meal source to the species level among vertebrates, and forensic techniques can be used to determine the individual blood donors for anthropophilic vectors, such as *Aedes aegypti* (L.) (Kent 2009).

In summary, we present data demonstrating an effective new device for collecting resting mosquitoes. This trap has the potential for facilitating vector ecology research and for augmenting surveillance for certain mosquito-borne pathogens (e.g., arboviruses, filarial nematodes, and malaria [*Plasmodium* species]), especially those pathogens transmitted by mosquitoes in the genera *Culex*, *Anopheles*, and *Culiseta*.

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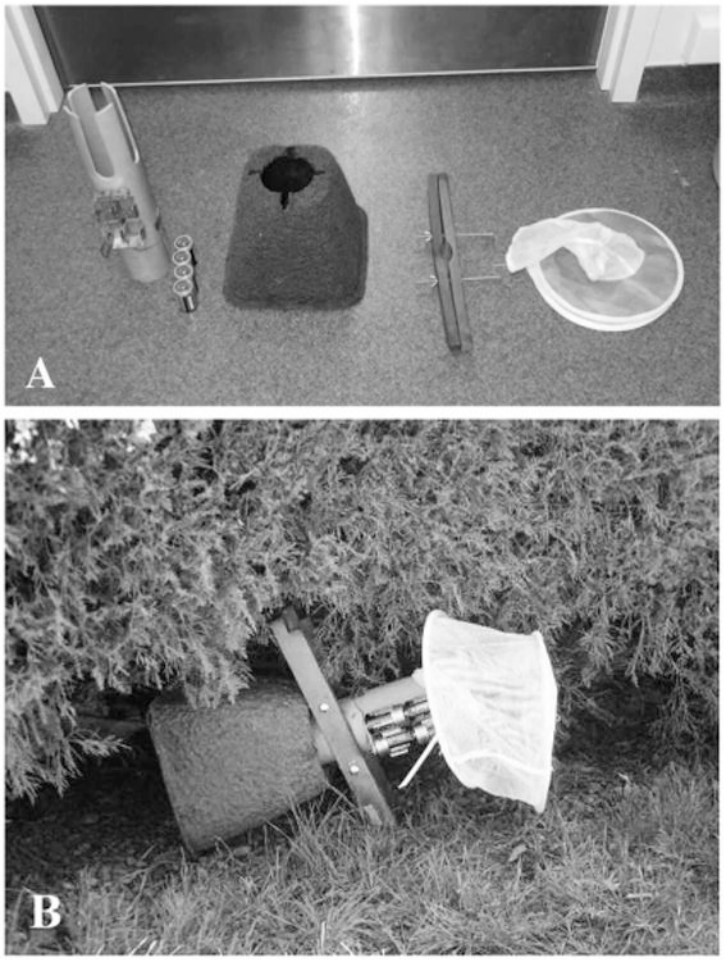

Fig. 1.
(A) Components of the Centers for Disease Control and Prevention resting trap. (B) Assembled resting trap.

Table 1

Mean number of adult female mosquitoes collected per trap-night by trap type (% bloodfed).[1]

Mosquito species	CDC[2] light trap (*n* = 19)	Wood-fiber pot (*n* = 920)	CDC resting trap (*n* = 115)
Aedes vexans	129.1 (2.0)	0.072 (4.5)	0.219 (0.0)
Culiseta inornata	1.8 (0.0)	0.023 (15.3)	0.057 (28.6)
Culex pipiens	2.6 (0.0)	0.037 (47.1)	0.848 (21.0)
Cx. restuans	0.1 (0.0)	0.007 (57.1)	0.057 (20.0)
Cx. tarsalis	45.5 (0.6)	0.380 (13.3)	2.18 (22.4)
Ae. dorsalis	11.1 (0.5)	0.004 (0.0)	0.019 (50.0)
Ae. melanimon	15.2 (0.0)	0.018 (17.6)	—
Ae. trivittatus	1.3 (0.0)	0.003 (0.0)	0.5 (0.0)
Ae. hendersoni	0.2 (0.0)	0.03 (0.0)	—
Cs. incidens	—	—	0.021 (0.0)
Cx. salinarius	—	—	0.007 (0.0)

[1] *n*, number of trap-nights.

[2] CDC, Centers for Disease Control and Prevention.