

Using Ovitrap to Assess the Quantity of Mosquito Larval Habitat During Local Eradication With Source Reduction and Ovitrap

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ABSTRACT The quantity of mosquito larval habitat in a specified area was assessed by placing a known number of ovitraps in the same area. The ovitraps competed for oviposition with the unknown quantity of larval habitat, and that quantity was deduced by comparing the number of eggs laid in the ovitraps when the number of ovitraps was changed from one time to another. This method can be used to assess the effectiveness of source reduction. It also provides key information for using ovitraps to eradicate local mosquito populations by competing with existing breeding sites for oviposition. The same ovitraps that are used for control can provide information on how many ovitraps are necessary to ensure eradication.

KEY WORDS *Aedes albopictus*, mosquito, ovitrap, larval habitat, eradication

Estimating the total quantity of larval habitat for container-breeding mosquitoes in a particular area can be useful for mosquito control, but it is often impractical to do it. Breeding sites in rain gutters, tree holes, small crevices in plants, and other places that collect rainwater may be virtually impossible to find. Even if the breeding sites can be found, enumerating them over a large area can require too much labor to be feasible. Moreover, the diversity of breeding sites makes it problematic to express the total quantity of larval habitat with a single number.

Estimating the quantity of larval habitat is of obvious value for planning and assessing source reduction. Comparing the quantity before and after source reduction can provide a measure of its effectiveness. Estimates of the quantity of larval habitat can be even more useful when source reduction is combined with the use of ovitraps to compete for mosquito oviposition at breeding sites not eliminated by the source reduction. While ovitraps have not often been used this way, the idea is not new. As early as 1905, H. R. Carter used “trap breeding-places” for the U.S. Public Health Service in Panama: “The breeding places of election being destroyed, the *Stegomyia* will be seeking others—usually more difficult to find. Put a couple of calabashes or a *tinaja* in a dark and shady place for her to lay in, which your inspector can turn over weekly. She will not seek the out-of-the-way-places” (Connor and Monroe 1923). Years later, a combination of ovitraps and source reduction eradicated *Aedes aegypti* (L.) from a residential neighborhood of ≈1,200 houses in the area surrounding Singapore’s international airport (Chan 1973). The ovitraps were

changed twice weekly to ensure that they did not produce mosquitoes.

The effectiveness of ovitraps was reaffirmed when *Aedes albopictus* (Skuse) disappeared from the vicinity of tire piles introduced to New Orleans woodlots (Marten 1990a). The tires contained copepods to ensure that larvae did not survive (Marten 1990b). Vietnam eradicated *Ae. aegypti* from hundreds of villages with a combination of source reduction and the introduction of copepods to domestic water storage containers, converting those containers into egg sinks (Nam et al. 1998, Kay and Nam 2005, Marten and Reid 2007). Other attempts to control mosquitoes with ovitraps have fallen short of eradication (Cheng et al. 1982, Perich et al. 2003, Sithiprasasna et al. 2003, Kitayapong et al. 2008, Regis et al. 2008), apparently due to an insufficient number of traps, insufficient duration of trapping, or defective traps.

Knowing the quantity of larval habitat could help to decide how many ovitraps are necessary to eradicate a mosquito population. To facilitate assessing the effectiveness of source reduction and extending control to the use of ovitraps, I have devised an indirect method for estimating the total quantity of *Aedes* larval habitat in a given area. Instead of enumerating breeding sites, this method assesses how much larval habitat there is by comparing the number of eggs laid in ovitraps when the number of those ovitraps is changed from one time to another. This report describes the method and illustrates its use with simple field data.

Materials and Methods

Derivation of Estimation Method. This method estimates the quantity (Q) of larval habitat in a specified

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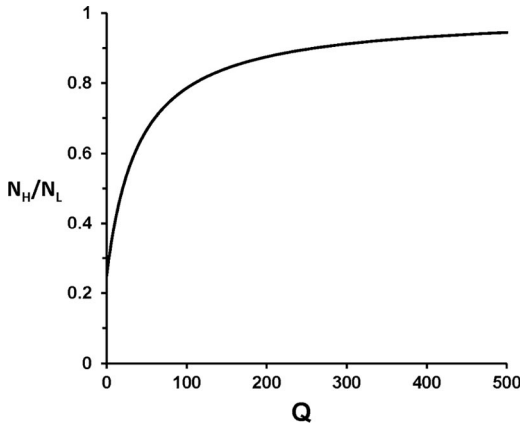


Fig. 1. Relationship between N_H/N_L (the ratio of average eggs laid per trap at high and low trap numbers) and Q (the quantity of larval habitat) according to equation 3. Trap numbers in this example are $T_H = 40$ and $T_L = 10$, and the values for \bar{N}_H/\bar{N}_L and \hat{Q} in Table 1 fall on the curve.

area by comparing the number of eggs laid in ovi-traps during a sequence of fixed time periods. The number of traps during each period alternates between a lower number (T_L) and a higher number (T_H). N is the average number of eggs laid each day, the eggs being distributed over the original breeding sites and the known number of traps (T_L or T_H).

The number of eggs per ovi-trap is less when the N eggs are distributed over a larger number of traps. How much less depends on the quantity of original larval habitat with which the eggs are shared. N_L is the average daily number of eggs laid in each ovi-trap with the low number of traps (T_L):

$$N_L = \frac{N}{T_L + Q} \tag{1}$$

The average daily number of eggs laid in each ovi-trap when the number of ovi-traps is high is

$$N_H = \frac{N}{T_H + Q} \tag{2}$$

Combining equations 1 and 2 and solving for Q :

$$Q = \frac{\frac{N_H T_H - T_L}{N_L}}{1 - \frac{N_H}{N_L}} \tag{3}$$

Equation 3 shows that N_H/N_L is the key to estimating Q . An examination of what happens at the extremes of that ratio can provide an intuitive understanding of how this estimation method works (Fig. 1). Assuming for illustrative purposes that the ovi-trap numbers are $T_L = 10$ and $T_H = 40$:

- If there is no original larval habitat at the site ($Q = 0$), eggs will be laid only in the ovi-traps. As a consequence, the average number of eggs per trap when there are 40 ovi-traps is one fourth the number of

eggs per trap when there are 10 ovi-traps. Thus, $N_H/N_L = 0.25$ when $Q = 0$.

- At the opposite extreme, if there is a very large quantity of original larval habitat compared with the number of ovi-traps, additional ovi-traps do not significantly affect the distribution of eggs among containers, and the average number of eggs per ovi-trap is about the same whether there are 10 ovi-traps or 40. In other words, $N_H/N_L \rightarrow 1$ as $Q \rightarrow \infty$.

Q can be estimated with equation 3, using observed average values of N_H and N_L :

$$\hat{Q} = \frac{\frac{\bar{N}_H}{\bar{N}_L} T_H - T_L}{1 - \frac{\bar{N}_H}{\bar{N}_L}} \tag{4}$$

where

$$\bar{N}_H = \frac{\sum_{i=1}^{n_H} \sum_{j=1}^{T_H} N_{Hij}}{\sum_{i=1}^{n_H} n_{Hi} T_{Hi}} \tag{4a}$$

n_H is the number of sampling periods with a high number of traps (T_H); N_{Hij} is the egg count from the j th trap during the i th sampling period; n_{Hi} is the number of days during the i th sampling period; and T_{Hi} is the number of traps whose egg counts were used for summation of N_{Hij} in the i th sampling period. (In practice, some N_{Hij} may be excluded from the summation in equation 4a because a trap was damaged or otherwise failed to provide a valid egg count for that sampling period.)

Correspondingly,

$$\bar{N}_L = \frac{\sum_{i=1}^{n_L} \sum_{j=1}^{T_L} N_{Lij}}{\sum_{i=1}^{n_L} n_{Li} T_{Li}} \tag{4b}$$

Once Q is estimated, it is straightforward from equation 2 to calculate the average total number of eggs laid each day:

$$\hat{N} = \bar{N}_H (\hat{Q} + T_H) \tag{5}$$

The estimated egg capture by the higher number of ovi-traps, as a percentage of all eggs (N) that were laid, is

$$\hat{C} = \frac{100 T_H}{(\hat{Q} + T_H)} \tag{6}$$

Standard Errors of Estimates. Following Wolter (1985, p. 126), the variance of \hat{Q} can be estimated by applying a first-order Taylor expansion to equation 4:

$$\begin{aligned} \text{Var}(\hat{Q}) &= \left(\frac{dQ}{d\bar{N}_H}\right)^2 \text{Var}(\bar{N}_H) + \left(\frac{dQ}{d\bar{N}_L}\right)^2 \text{Var}(\bar{N}_L) \\ &+ 2 \left(\frac{dQ}{d\bar{N}_H}\right) \left(\frac{dQ}{d\bar{N}_L}\right) \text{Cov}(\bar{N}_H, \bar{N}_L) \tag{7} \\ \frac{dQ}{dN_H} &= \frac{N_L (T_H - T_L)}{(N_L - N_H)^2} \end{aligned}$$

$$\frac{dQ}{dN_L} = \frac{N_H(T_L - T_H)}{(N_L - N_H)^2}$$

Assuming $\text{Cov}(\bar{N}_H, \bar{N}_L) = 0$, the standard error of \hat{Q} is

$$\text{SE}(\hat{Q}) = \sqrt{\frac{(\bar{N}_L T_H - \bar{N}_L T_L)^2 \text{Var}(\bar{N}_H)}{(\bar{N}_L - \bar{N}_H)^4} + \frac{(\bar{N}_H T_L - \bar{N}_H T_H)^2 \text{Var}(\bar{N}_L)}{(\bar{N}_L - \bar{N}_H)^4}} \quad [8]$$

where $\text{Var}(\bar{N}_H)$ and $\text{Var}(\bar{N}_L)$ are estimated from variation in the original egg counts (N_{Hij} and N_{Lij}) as follows. For the high number of traps, $\text{Var}(N_{Hij})$ is based on the sum of the squared deviations of the observed daily egg counts from \bar{N}_H , using the same egg counts that were used to calculate \bar{N}_H with equation 4a and weighting each squared deviation in proportion to the number of days in each sampling period:

$$\text{Var}(N_{Hij}) = \frac{\sum_{i=1}^{n_H} n_{Hi} \sum_{j=1}^{T_H} \left(\frac{N_{Hij}}{n_{Hi}} - \bar{N}_H \right)^2}{\sum_{i=1}^{n_H} n_{Hi} T_{Hi}}$$

As with equation 4a, missing data among the N_{Hij} are skipped in the summation. Dividing $\text{Var}(N_{Hij})$ by the sample size $\sum_{i=1}^{n_H} T_{Hi}$:

$$\text{Var}(\bar{N}_H) = \frac{\sum_{i=1}^{n_H} n_{Hi} \sum_{j=1}^{T_H} \left(\frac{N_{Hij}}{n_{Hi}} - \bar{N}_H \right)^2}{\left(\sum_{i=1}^{n_H} T_{Hi} \right) \left(\sum_{i=1}^{n_H} n_{Hi} T_{Hi} \right)} \quad [8a]$$

Similarly,

$$\text{Var}(\bar{N}_L) = \frac{\sum_{i=1}^{n_L} n_{Li} \sum_{j=1}^{T_L} \left(\frac{N_{Lij}}{n_{Li}} - \bar{N}_L \right)^2}{\left(\sum_{i=1}^{n_L} T_{Li} \right) \left(\sum_{i=1}^{n_L} n_{Li} T_{Li} \right)} \quad [8b]$$

The procedure for estimating $\text{SE}(\hat{Q})$ from field data is first to calculate $\text{Var}(\bar{N}_H)$ and $\text{Var}(\bar{N}_L)$ with equations 8a and 8b and then use those estimates to calculate $\text{SE}(\hat{Q})$ with equation 8.

Applying Taylor expansions to equations 5 and 6,

$$\text{SE}(\hat{N}) = \sqrt{\frac{(\bar{N}_L^2 T_H - \bar{N}_L^2 T_L)^2 \text{Var}(\bar{N}_H)}{(\bar{N}_L - \bar{N}_H)^4} + \frac{(\bar{N}_H^2 T_L - \bar{N}_H^2 T_H)^2 \text{Var}(\bar{N}_L)}{(\bar{N}_L - \bar{N}_H)^4}} \quad [9]$$

$$\text{SE}(\hat{C}) = \frac{\hat{C}}{\hat{Q} + T_H} \text{SE}(\hat{Q}) \quad [10]$$

Demonstration of Method. Tests of the method were conducted at five residential sites in New Orleans, each $\approx 500 \text{ m}^2$. Although the most conspicuous larval habitats were gardening buckets and dishes under flower pots, the abundance of *Ae. albopictus* adults suggested large quantities of hidden larval habitat.

At each site, 40 355-ml (12-oz) black plastic cups (little black jar [LBJ] traps) were distributed around the entire property. Each cup was three-quarters filled with rearing water from an *Ae. albopictus* laboratory colony as an oviposition attractant. Each cup also contained a strip of red velour paper (5 cm in width) attached with a paper clip to the inside of the cup and extending from the top of the cup to the bottom. The traps were designed to attract as many eggs as possible to increase egg sample size for more precise estimates of Q , N , and C . Previous field experiments with paired cups established that 1) single paper strips attracted almost as many eggs as paper wrapped all the way around a cup and 2) larval rearing water attracted approximately twice as many eggs as tap water. Attractiveness of the traps should have no other effect on the estimates as long as the average attractiveness of the T_H and T_L traps is the same.

The low number of cups (T_L) was 10, and the high number (T_H) was 40. The number of cups was reduced to 10 by putting plastic lids on 30 of the cups, selected at random whenever there was a reduction in number. The number was returned to 40 by removing the lids.

There were three sampling periods with low trap numbers and three periods with high traps (i.e., $n_H = n_L = 3$). All the sampling periods (n_{Hi} and n_{Li}) were 3 d in duration, alternating back and forth between 10 and 40 cups, for a total of 18 d. Three days was selected as the sampling period duration because it provided a larger sample of eggs than a single day, whereas eggs were still countable because there were not so many eggs that they were on top of each other on the velour strips. The strips were removed from the cups and replaced with new ones at the end of every 3-d period, and the number of *Ae. albopictus* eggs on removed strips was counted with a stereomicroscope. Water in the cups was replaced with fresh larval rearing water whenever velour strips were replaced. The field sites were known to have no significant number of other mosquito species (e.g., *Ae. aegypti* or *Aedes triseriatus* Say) whose eggs might be confused with *Ae. albopictus*.

The total number of eggs during all of the periods with 40 cups was used to calculate a daily average (\bar{N}_H) with equation 4a, and the same procedure was followed to calculate \bar{N}_L from the periods with 10 cups. The 3-d alternation between the low and high number of cups ensured that the average number of eggs laid each day (N) was approximately the same for the periods with a low number of cups and the periods with a high number, despite day-to-day weather fluctuations that could affect mosquito oviposition activity.

Results and Discussion

Table 1 shows the estimates for Q , N , and C at the five field sites. The differences between \bar{N}_H and \bar{N}_L are in the expected direction (i.e., $\bar{N}_H < \bar{N}_L$). $\text{SE}(\hat{Q})/Q$ is

Table 1. Field data and estimates (\pm SE) from five sites in New Orleans

Site	Observations			Estimates		
	\bar{N}_H^a	\bar{N}_L^b	\bar{N}_H/\bar{N}_L	\hat{Q}^c	\hat{N}^d	\hat{C}^e
A	4.41 (0.15)	12.40 (0.43)	0.356	6.56 (1.27)	205 (12)	85.9 (2.4)
B	9.73 (0.50)	21.44 (1.09)	0.454	14.93 (3.29)	534 (55)	72.8 (4.4)
C	9.29 (0.45)	11.87 (0.57)	0.783	98.1 (33.7)	1,282 (360)	29.0 (7.1)
D	4.98 (0.38)	6.45 (0.49)	0.772	91.6 (48.2)	656 (278)	30.4 (11.1)
E	4.06 (0.38)	4.32 (0.41)	0.940	459 (1040)	2,024 (4,361)	8.0 (16.7)

^a Average daily number of eggs laid in each ovitrap when there were 40 ovitraps, estimated with equation 4a. SE(\bar{N}_H) estimated with equation 8a as $\sqrt{\text{Var}(\bar{N}_H)}$.
^b Average daily number of eggs laid in each ovitrap when there were 10 ovitraps, estimated with equation 4b. SE(\bar{N}_L) estimated with equation 8b as $\sqrt{\text{Var}(\bar{N}_L)}$.
^c Quantity of larval habitat (in ovitrap units), estimated with equation 4. SE(\hat{Q}) estimated with equation 8.
^d Average total number of eggs laid each day (distributed over ovitraps and original breeding sites), estimated with equation 5. SE(\hat{N}) estimated with equation 9.
^e Percentage of all eggs captured by ovitraps when T_H was 40, estimated with equation 6. SE(\hat{C}) estimated with equation 10.

relatively small at sites A and B, where the difference between \bar{N}_H and \bar{N}_L is most pronounced ($N_H/N_L = 0.356$ for site A and $N_H/N_L = 0.454$ for site B). The difference between \bar{N}_H and \bar{N}_L at sites C and D is less, and the standard errors of the estimates are correspondingly higher. There is little difference between \bar{N}_H and \bar{N}_L at site E, and the standard errors are so large that the results are useless. The high standard errors for sites C, D, and E indicate that 40 cups were not enough to compete decisively for oviposition with the larval habitat that was already there. It would be necessary to have more traps at sites C, D, and E to generate more precise estimates of Q .

Sampling Design. Fig. 1 shows why SE(\hat{Q}) is smaller when the difference between N_H and N_L is more pronounced. Smaller values of N_H/N_L , such as N_H/N_L from 0.25 to 0.7 in Fig. 1, provide the greatest “leverage” for estimating Q . In this range, small differences in N_H/N_L correspond to small differences in Q , so variation in \bar{N}_H/\bar{N}_L due to sampling error will generate a relatively small variance in \hat{Q} , as happened at sites A and B in Table 1. In contrast, when $N_H/N_L > 0.7$, small differences in N_H/N_L correspond to large differences in Q , and sampling variation in \bar{N}_H/\bar{N}_L is amplified into unacceptably large variance in \hat{Q} as happened at sites C, D, and E.

Focusing on how T_H affects the precision of \hat{Q} , increases in T_H can reduce SE(\hat{Q}) in two ways:

- A larger high number of traps competes more with existing breeding sites for the fixed number of eggs (N), reducing N_H , and consequently increasing the difference between N_L and N_H that provides the leverage for estimating Q .
- A larger number of traps increases the sample size $n_H T_H$, providing a more precise estimate of N_H , and therefore a more precise estimate of the difference between N_H and N_L for estimating Q .

Figure 2 shows that SE(\hat{Q}) declines dramatically in the left half of the curve, as T_H increases from 0 to Q . This decline is mainly because higher T_H increases the difference between N_L and N_H . When $T_H > Q$, Fig. 2 shows that increases in T_H continue to reduce SE(\hat{Q}),

but the main effect here is through the increase in the sample size, whose contribution to the precision of Q is to reduce SE(\hat{Q}) in proportion to $1/\sqrt{n_H T_H}$. An increase in sample size can be achieved by increasing the number of sampling periods, the number of traps, or both. A quadrupling of sample size is necessary to cut SE(\hat{Q}) in half.

How about T_L ? Figure 3 shows that SE(\hat{Q}) is very high when $T_L/T_H < 0.02$, because the sample size for estimating N_L is so small. SE(\hat{Q}) is lowest when T_L is 13% of T_H , although SE(\hat{Q}) is almost equally low over a broad range from 5 to 30% of T_H . SE(\hat{Q}) becomes unacceptably high when $T_L/T_H > 0.5$, because N_L is reduced, consequently reducing the difference between N_L and N_H that provides leverage for estimating Q . In addition to the sampling considerations represented by Fig. 3, it is better for T_L/T_H not to be at the low end of the 0.05–0.30 range because a very small number of traps for measuring N_L could by chance represent more attractive or less attractive oviposition conditions in a heterogeneous environment. As a rule, T_L should be at least 20% of T_H for \bar{N}_L to embrace a representative average of oviposition conditions.

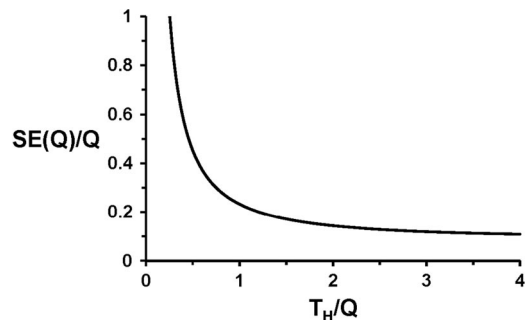


Fig. 2. Dependence of SE(\hat{Q}) on the higher number of traps (T_H), expressed as a proportion of the quantity of larval habitat (Q). This example, based on equation 8, assumes that $T_L = 0.2T_H$, $n_H = n_L = 10$ single-day sampling periods, and the standard deviations of N_{Hij} and N_{Lij} during the sampling periods are equal to the averages of N_{Hij} and N_{Lij} .

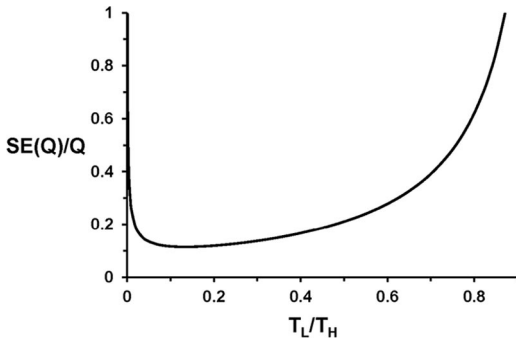


Fig. 3. Dependence of $SE(\hat{Q})$ on the lower number of traps (T_L), with $SE(\hat{Q})$ expressed as a proportion of the quantity of larval habitat (Q) and T_L expressed as a proportion of the higher number of traps (T_H). This example, based on equation 8, assumes that $T_H/Q = 3$, $n_H = n_L = 10$ single-day sampling periods, and the standard deviations of N_{Hij} and N_{Lij} during the sampling periods are equal to the averages of N_{Hij} and N_{Lij} .

Further experience with the method could reveal new ways to improve its precision. One possibility is to reduce $\text{Var}(\hat{Q})$ by taking advantage of the covariance term in equation 7. Some traps may attract more eggs than other traps because of their exact location at a site. If those traps consistently attract more eggs whether the number of traps is high or low, and other traps consistently attract fewer eggs, it could be advantageous to compare average egg counts (\bar{N}_{Hj} and \bar{N}_{Lj}) trap by trap to estimate N_H/N_L for equation 3. This might use egg counts for the high number of traps only from exactly the same traps and trap locations used for the low number of traps, leaving the rest of the T_H traps out of the calculations. This procedure could reduce the labor required for counting eggs while also reducing $\text{Var}(\hat{Q})$ if there is a significant positive correlation between \bar{N}_{Hj} and \bar{N}_{Lj} . Details of estimation equations will depend on details of statistical design. The practical merits of alternative designs can be ascertained with more experience collecting egg trap data in a variety of field situations.

Bias in Estimates. How well does this method really work? There may be bias that is difficult to detect or correct. For example, a key underlying assumption for estimating Q is that the average number of eggs laid each day (N) is the same whether the number of traps is high (T_H) or low (T_L). While random day-to-day fluctuations in N could increase $\text{Var}(\bar{N}_H)$, $\text{Var}(\bar{N}_L)$, and therefore $\text{Var}(\hat{Q})$, variation in N could create a bias if the expected values of \bar{N}_H and \bar{N}_L are different when the number of traps is different. For example, female mosquitoes might hold onto eggs when oviposition sites are scarcer and lay more eggs when oviposition sites are more plentiful, leading to overestimation of Q .

The assumption that N is the same regardless of the number of traps could be tested by placing ovitraps in an area known to contain no larval habitat (i.e., $Q = 0$) and allowing a mosquito population to take hold by using the ovitraps for breeding. Then, alternating be-

tween high and low numbers of traps, the assumption that N is the same for both situations would be confirmed if $\bar{N}_H T_H$ is observed to be the same as $\bar{N}_L T_L$.

Other field experiments could check the validity of the estimation method in the face of unknown sources of bias. For example, the general validity of equation 3 could be probed by manipulating larval habitat to produce known increments in Q and seeing how well the resulting increments in \hat{Q} correspond to the known increments. The field site might be a cemetery where flower vases could be added or removed.

Estimating Number of Ovitrap Needed for Local Eradication. It is not the purpose of this publication to thoroughly explore strategies for eradicating mosquitoes with ovitraps, but a brief examination can suggest how estimation of Q could contribute to the process. The number of ovitraps needed for eradication depends not only on how much larval habitat there is but also what percentage of the mosquito eggs must be wasted in ovitraps to bring about population collapse. Knipling (1970) did a simple theoretical analysis that indicated local eradication could be expected only if ovitraps outnumber breeding sites by at least 10:1. I have explored the same issue using the computer simulation model of Focks et al. (1993) for *Ae. aegypti* population dynamics. Results from that model indicate that ovitraps must attract at least 90% of all eggs laid to achieve local eradication, a result almost identical to Knipling's. However, in Vietnam converting as few as 65% of a village's water storage containers into egg traps with copepod introductions has led to local eradication of *Ae. aegypti* within 2 yr (Nam et al. 2005).

Table 1 illustrates how estimates of Q and C can help to decide how many ovitraps are needed for local eradication. Assume for illustrative purposes that 1) the estimates in Table 1 are correct, 2) local eradication requires at least 80% of all eggs laid to go into ovitraps, and 3) the site is not flooded by mosquitoes from the surrounding area. The estimated egg capture by the 40 ovitraps at site A is $\hat{C} = 86\%$, suggesting that 40 ovitraps are about right for that site. A few more traps would be needed at site B, where $\hat{C} = 73\%$. Substantially more traps would be necessary for sites C, D, and E. A better idea of how many traps would be necessary for sites C, D, and E could come from a more precise estimate of C with field data using more traps (T_H and T_L) and possibly more sampling periods (n_H and n_L).

However, the required number of ovitraps, when deployed on a larger scale than the residential properties in this study, could actually be less than suggested by the estimates in Table 1 because each estimate in Table 1 applies to a larger area than the area occupied by the traps. The traps were competing not only with larval habitat in the area where they were placed, but also (because of mosquito movement) with larval habitat in the surrounding area. When the area with traps is small, simply dividing \hat{Q} by the area with traps can overestimate the quantity of larval habitat per unit area and therefore overestimate how many traps per unit area are needed for local eradi-

cation. A straightforward way to deal with this complication is for the traps to cover a large enough area, compared with the distance traveled by mosquitoes, so this "edge effect" is insignificant.

In conclusion, although Table 1 illustrates the use of ovitraps to assess larval habitat, the validity of the method remains to be confirmed. The most rigorous verification would come from field tests where larval habitats are completely known. Beyond that, best procedures should become apparent with experience using the method in practical mosquito control.

Potentially, ovitraps can be used to

- Assess the quantity of larval habitat that requires control treatment. Assessment is in terms of oviposition attraction (Wong et al. 2011), not the capacity of the habitat for mosquito production, although the two should be correlated.
- Assess the effectiveness of source reduction by estimating the quantity of larval habitat before and after source reduction.
- Estimate the number of ovitraps that would be necessary for local eradication. The same traps that are used for eradication can be used to assess the quantity of larval habitat with which the traps are competing. When ovitraps outnumber larval habitat enough to achieve eradication, the large sample size for egg counts and the high value of T_H/Q will generate precise estimates of Q and C (Fig. 2).
- Assess adult mosquito populations by estimating N and converting to the number of mosquitoes by means of information on the number of eggs laid per mosquito (Maciel de Freitas et al. 2011).

Although the demonstration in this study was conducted on single residential lots, future use should be on a larger scale. Neighborhoods make sense for source reduction and the use of ovitraps to assess its effectiveness. Likewise, a neighborhood scale is appropriate when using ovitraps for eradication. If $SE(\hat{Q})/Q$ from a first round of trapping is unacceptably high, equation 8 can be used, as illustrated in Figs. 2 and 3, to calculate how many more traps (T_H and T_L) or sampling periods (n_H and n_L) should generate acceptably precise estimates of Q in subsequent rounds. Standardization of trap design, trap water quality, and anything else affecting the attractiveness of traps to oviposition will be requisite to comparing Q at different times or places.

Although application of equations 4, 5, and 6 for estimating Q , N , and C is most obvious for container-breeding habitats, the same method could conceivably be used for other kinds of mosquitoes as long as some kind of ovitrap is involved. For example, *Culex* breeding sites may be beyond enumeration because they are located in storm drains. It might be possible to use gravid traps not only to compete with the *Culex* breeding sites in a specified area but also to assess the quantity of larval habitat by using different numbers of gravid traps at different times.

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