

Editorial

Malaria Elimination: When the Tools Are Great but Implementation Falters

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In the current issue of the *American Journal of Tropical Medicine and Hygiene*, Silas Majambere and colleagues¹ report the outcome of a trial to control malaria in rural parts of The Gambia through larval source management (LSM). In response to the increased uptake of treated bed nets and indoor residual spraying across Africa, various integrated programs that include LSM have been, or are being implemented, in line with the World Health Organization's (WHO) advocacy of integrated vector management (IVM).² Area-wide larviciding thus seemed an attractive integral component for IVM along the Gambia River where annual flooding produces numerous breeding sites in the first kilometer of landward edges of the river. Parallel to this study, several authors were also engaged in a similar trial in West Kenya, the results of which were published recently,³ which showed unequivocally that larval control significantly enhanced the impact of bed net use only. Regretfully, in The Gambia the trial failed, with no reduction in clinical malaria, parasite prevalence, or anemia. This trial failed despite a massive 88% reduction in apparent larval densities. What went wrong?

In both trials larviciding was executed by treating anopheline breeding sites at weekly intervals with the biological control agent *Bacillus thuringiensis israelensis* (Bti). In both sites the efficacy of the agent was demonstrated before full-scale field application. It cannot be concluded otherwise, therefore, that the tool *per se* cannot be the cause for the observed differences. Bti worked well against mosquitoes in Kenya, and so it did in The Gambia. The remaining causes for the observed differences in outcome could be based on differences in the ecology and behavior of local vector populations, the nature of the mosquito breeding habitat, or the way in which the larval control campaigns were executed. Perhaps all three factors interfered in some way.

The authors considered the likelihood of mosquitoes dispersing over considerable areas (from outside the treated zones into the areas where larviciding took place) as unlikely, based on former mosquito dispersal studies. Nevertheless, although it was assumed that mosquitoes primarily bred along the river they were later found to occupy much larger areas of the floodplain. Second, they considered the possibility that females oviposited on damp soil, a phenomenon observed elsewhere in Africa. Flooding of these eggs during tidal movements might yield new larvae that escaped larvicidal treatment. The previous two points indicate that 1) potential breeding habitat went untreated, and 2) sites remained untreated after flooding. Although the latter sites should always have received treatment within the following week,

this apparently did not happen, or at least not before such sites produced adults.

The last and perhaps most critical cause of failure was described as "...we cannot exclude the possibility that field applicators may have missed aquatic habitats." Coverage of all potential aquatic habitats with larviciding was hindered by inaccessibility caused by deep water and other terrain features that made it impossible for field applicators carrying knapsack sprayers to reach all parts of the areas that had to be covered. It seems likely therefore that the more than originally anticipated and widespread breeding, combined with incomplete coverage of potential vector habitat, supported an overall lower but still viable vector population that sustained parasite transmission at levels that did not result in any changes in malarial indices. As such, the outcome fits the previously described non-linear relationship between transmission intensity and prevalence.⁴ Or simply stated: Good vector control is not always good enough in terms of disease control.

Although the trial was considered a failure, the lessons learned are of crucial importance. First, the tool may be perfect, but if the application of it is not than failure is imminent. Although the authors wanted to test ground application of larvicides as an appropriate model for community engagement in resource-poor African settings, they concluded that aerial application would likely have yielded more impact. I fully support this conclusion, particularly at the dawn of the second eradication era, where compromises in terms of the rigor in which campaigns are executed are simply not acceptable. If indeed elimination is the long-term goal, than the organization of LSM will have to match the prerequisites for success that typified large-scale historical campaigns, notably the eradication of *Anopheles arabiensis* from Brazil and Egypt.⁵ Finally, any vector control strategy that moves beyond the household and individual level will have to consider the principles of "area-wide pest management," where scale becomes a factor of overriding importance. Area-wide control of vector populations implement control strategies that become increasingly effective when applied with consideration of spatial factors that will increase their effect: the extent of the area over which control is implemented itself becomes a new tool. While not inconsistent with community and individual methods, area-wide programs do not require personally intrusive fine-scale methods like bed nets or indoor residual spraying. Area-wide methods are often made effective and sustainable by initial reductions in pest populations achieved by conventional control or seasonal variation in vector abundance.⁶ Scale and strategy matter.

Twenty years ago we compromised on the number of insecticide-treated targets to control the tsetse fly *Glossina morsitans centralis* in Western Zambia, by only placing targets around the perimeter of extensive Miombo woodland areas rather than placing them grid-wise throughout the area

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(at a much higher cost). The trial failed.⁷ Majambere and others rightly end their work with a call for the development of a decision support system to determine when, where, and how LSM may augment or become a key element of IVM strategies. One thing is clear: Any form of compromise in terms of tool implementation, (area-wide) coverage or stringency in campaign execution will hold the recipe for failure.

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