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LETTERS TO THE EDITOR
HABITAT TARGETING FOR CONTROLLING AQUATIC STAGES OF MALARIA VECTORS IN AFRICA

The publication of several articles of immediate relevance in recent weeks has prompted the authors to revise this letter immediately prior to publication. It was not possible to incorporate these changes at the proof stage so the revised version is available at www.ajtmh.org.

Dear Sir:

Gu and Novak[1] have recently highlighted the potential for improving the cost-effectiveness of mosquito larval control as a malaria prevention measure in Africa, if the most productive habitats could be identified and targeted. We agree that this is, in principle, a valid hypothesis that probably holds true to some extent in real African field situations. However, we do have three major reservations that have substantial implications for the development of operational mosquito control programs in the poorest nations of tropical Africa. In the absence of a contemporary evidence base for the application of source reduction in Africa, we suggest the following caveats should be considered as the operational research community strives to translate the recent wave of historical review, theoretical elucidation, and supporting field ecology studies into sustainable, cost-effective programs that kill mosquitoes and prevent malaria. We outline each concern in increasing order of importance:

First, we suggest that their mathematical description underestimates the likely impact of untargeted control. Specifically, we believe that equation 2 (described as S2 in their paper) does not accurately represent the untargeted scenario it is intended to. The authors acknowledge that many aspects of the model have been adapted to represent conditions under which the phenomenon in question is most obvious and important. The approach they endorse has been restricted to settings of modest endemicity where targets for reducing transmission intensity are less intimidating,[2,3] but we would prefer to have seen a range of settings and underlying conditions explored to put the frequency of these restricted conditions into perspective. Furthermore, we believe the formulation described in equation 2 exaggerates the advantage of targeting at low coverage levels, even under the conditions of modest endemicity specified in this paper. In an untargeted scenario, all habitats should have an equal chance of being covered if they are readily visible and accessible, as is usually the case for *Anopheles gambiae* Giles but far less so for *Anopheles funestus* Giles.[4–7] Thus, effective coverage should be directly proportional to overall coverage, regardless of the distribution of productivities, unless the number of productive habitats is so small that they are easy to miss at low coverage. We suggest such concentration of productivity in a handful of cryptic habitats is unlikely to be the case in many, if not most, parts of Africa. We interpret equation 2 in the formulation of Gu and Novak as representing an active bias against treatment of productive habitats, resulting in a much larger gap between effective coverage of targeted and untargeted scenarios at coverage levels less than 60%. Additionally, the logistic function presented has two tunable parameters (α and β) that seem to have been set to arbitrary values to provide a relationship that fits with the hypothesis proposed. This equation could be tuned to provide a number of curves, some of which could be related to this issue but most of which cannot. Of particular concern is the fact that this equation will not yield $P = 1$ where $C = 0$ nor $P = 0$ where $C = 1$ unless discontinuously defined. Furthermore, we cannot reproduce the relationship described for S2 in Figure 1 using the equation provided and parameter values listed, getting instead a flat saturated line with values of 99.7% for all values of coverage from 0% to 100%. Despite these criticisms, we accept that equation 3, representing the targeted scenario (S3), is useful and still makes the point that targeting would represent an improvement on an untargeted scenario. We conclude that the point the authors are making is theoretically valid, but untargeted larviciding can be represented more accurately and convincingly by the existing simple, linear form presented in equation 1 of their paper, as previously described.[8]

Our second concern relates to the interpretation of our published work.[9,10] The major conclusion we reached in both of these papers is that some heterogeneities of apparent productivity do exist, but they are not sufficiently large or predictable enough to enable rational targeting. Furthermore, distribution of habitats themselves is highly dynamic and represents a moving target, even without considering variations in productivity. Meteorological fluctuations combine with underlying hydrology and human activity to generate a constantly changing array of potential habitats. This is particularly true for notoriously opportunistic members of the *An. gambiae* species complex, for whom the majority of habitats are usually man-made, even in rural settings.[5,9–15] Thus, while we agree in principle with the hypothesis presented by the authors, we suggest that the magnitude of variation in productivity between habitats remains poorly understood and difficult to predict in real field situations. Despite our long experience with sampling *Anopheles* larvae in a variety of sites across Africa, we are unable to reach consensus about what the most consistently productive habitat types are or where we would look for them on a given day in a given setting. Even if the research community could reach consensus on where to direct interventions, we raise the question as to whether this knowledge could be translated into success under operational conditions.

Our third concern relates to the likely impact of targeting specific habitats under programmatic conditions. We share the expectation that ongoing trials of larval control across Africa will prove that appropriate larvicides are efficacious in the hands of specialized research teams under the conditions of randomized control trials. Nevertheless, experience with a range of public health interventions has highlighted the massive gap between proving efficacy and achieving effectiveness.[16] By necessity, sustainable operational programs to be implemented at national scales in Africa will be predominantly staffed by personnel with minimal educational qualifications and modest remuneration, under very challenging climatic conditions. We therefore envisage that translation of presently debatable ecological subtleties into rational targeting will be extremely challenging. Furthermore, we have found a variety of existing preconceptions in communities throughout Africa about where mosquitoes originate from and an enormous variation in perceptions of where best to target between individuals within the same locality. We have experienced that consideration of such perceptions in decisions to apply larvicides results in inconsistent levels of coverage and targeting. It also makes management of such programs, even on small scales, almost impossible because it allows a range of reasons for not having treated a habitat, making the "individualization of responsibility," which Soper himself emphasized,[6,17] very difficult to realize in practice.

The most historically successful campaigns against African malaria vectors have all included exhaustive coverage with larval control strategies.[6,7,17–21] One secret of success in these endeavors, particularly the Brazilian and Egyptian campaigns, was the simple and readily verifiable targets provided to field workers at the sharp end of the mosquito control spear: to kill all mosquitoes. This "shoot first, ask questions later" philosophy may seem crude in the modern era, but its success remains unrivaled, and to implement it today is a challenge in itself. We therefore support the hypothesis of Gu and Novak but urge caution in considering the merits of targeting strategies under research and programmatic conditions. Unambiguous criteria for targeting may need to be established through consensus among the scientific community. If this can be achieved, we conclude that these new tools could be evaluated as system interventions by comparing with comprehensive coverage through large-scale effectiveness trials under programmatic conditions.

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