Can Mosquito Magnet® substitute for human-landing catches to sample anopheline populations?

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The efficiency of the Mosquito Magnet Liberty Plus™ (MMLP) trap was evaluated in comparison to human-landing catches (HLCs) to sample anopheline populations in Jabillal, state of Bolivar, southern Venezuela. The village comprised 37 houses and a population of 101; malaria in this village is primarily due to Plasmodium vivax *and the Annual Parasite Index is 316.8 per 1,000 population. A longitudinal study was conducted between June 2008-January 2009 for three nights per month every two months between 17:30 pm-21:30 pm, a time when biting mosquitoes are most active.* Anopheles darlingi *and* Anopheles nuneztovari *were the most common species collected by both methods, whereas* Anopheles marajoara *was more abundant according to the HLC method. The MMLP trap was more efficient for collecting* An. nuneztovari *[63%, confidence interval (CI): 2.53] than for collecting* An. darlingi *(31%, CI: 1.57). There were significant correlations ($p < 0.01$) between the two methods for* An. darlingi *[Pearson correlation (R^2) = 0.65] and* An. nuneztovari *($R^2 = 0.48$). These preliminary results are encouraging for further investigations of the use of the MMLP trap for monitoring anopheline populations in remote malaria-endemic areas in the Amazon Basin.*

Key words: malaria vectors - Mosquito Magnet Liberty Plus - Venezuela

In entomological studies on malaria transmission and the evaluation of vector control programmes, it is necessary to estimate the human biting rate, i.e., the number of female mosquitoes found per person per night (WHO 1975). For more than 70 years, host-seeking anophelines have been collected by catching mosquitoes landing on humans. Nevertheless, this method faces several ethical and practical objections. Thus, substantial efforts have been made to find an efficient method for sampling anopheline populations that would eliminate or minimise the use of human-landing catches (HLCs) for the routine evaluation of control programmes, especially in southern Venezuela and similar areas. In such areas, large numbers of cases are due to *Plasmodium falciparum*, which is resistant to several drugs (Caraballo & Rodríguez-Acosta 1999, Contreras et al. 2002).

Previous longitudinal studies conducted in Venezuela to evaluate different trapping methods have shown contrasting results. For instance, CDC light traps set beside two human baits protected by mosquito nets caught only 10% of the *Anopheles (Nyssorhynchus) nuneztovari* Gabaldon collected during HLCs, although the trap was more efficient for sampling *Anopheles (Nyssorhynchus) marajoara* Galvão & Damasceno and *Anopheles (Nyssorhynchus) oswaldoi* (Peryassú) (Rubio-Palis & Curtis 1992). In addition, CDC light traps baited with carbon dioxide (CO_2) and/or 1-octen-3-ol (octenol) proved less efficient for sampling populations of *Anopheles (Nyssorhynchus) aquasalis* Curry and *Anopheles albimanus* Wiedemann than updraft ultraviolet (UV) light traps baited with CO_2 compared with HLCs (Rubio-Palis 1996). Conversely, studies conducted in gold-mining areas of the state of Bolívar, southern Venezuela, showed that, compared with HLCs, CDC light traps were more efficient for sampling *Anopheles darlingi* Root and *An. marajoara* than the updraft UV light trap; nevertheless, both methods collected less than 30% of the mosquitoes landing on humans (Moreno et al. 2002). In the Upper Orinoco River, state of Amazonas, it was shown that, compared with HLCs, the CDC light trap was more efficient (62%) than the updraft UV light trap (45%) for collecting *An. darlingi* (Rubio-Palis et al. 1999). Preliminary studies conducted in the Caura River Basin, municipality of Sucre, Bolívar, reported that the CDC light traps and updraft UV light traps are inefficient in endemic areas where the abundance of biting anopheline populations is low (Rubio-Palis et al. 2010).

Several studies have shown that Mosquito Magnet® (MM) traps (American Biophysics Corporation, North Kingstown, RI) are more efficient than CDC light traps baited with CO_2 and/or octenol to collect mosquitoes (Brown et al. 2008, Xu et al. 2008, Hoel et al. 2009, Dusfour et al. 2010, Hiwat et al. 2011a). Although it has been shown that the traps can be used for mosquito control and routine surveillance, the MM traps are marketed for the control of blood-seeking insects in residential areas (mosquitomagnet.com), although the traps have shown that can be used for mosquito control and routine surveillance (Pucci et al. 2003, Brown et al. 2008, Xu et al. 2008, Kitau et al. 2009,

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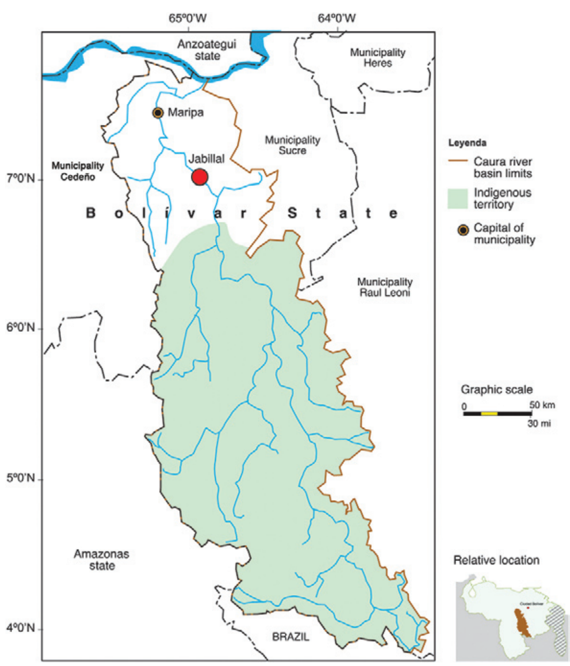
2010). The MM trap is battery operated and utilises CO_2, one of the products of the catalysis of propane gas, as an attractant (Kline 1999). In addition, other attractants, such as octenol and L-lactic acid, have been evaluated (Pucci et al. 2003, Cileck & Hallmon 2005, Kitau et al. 2009, 2010, Dusfour et al. 2010).

To evaluate the efficiency of the Mosquito Magnet Liberty Plus™ trap + octenol (MMLP) compared with HLCs to collect anophelines, a longitudinal study was conducted between June 2008-January 2009 in Jabillal (07º03'43"N 64º58'37"W), a location along the Caura River (Fig. 1). The village has 37 houses distributed along a dirt road and 101 inhabitants; malaria in the village is due primarily to *Plasmodium vivax*, with an Annual Parasite Index of 316.8 per 1,000 population (ISP 2008). Three collection stations were established outside selected houses. We placed two MMLP traps 200 m apart, one approximately 20 m from the first house and the other near the middle of the village; two members of the research team, acting as human baits, were located at the other end of the village, approximately 150 m from the latter MMLP trap (mid-village). The present design did not incorporate site differences in mosquito collections because the methods were not rotated. A cartridge containing 1.660 mg of octenol (active ingredient, 55.15%) was placed in the plume chamber of each MMLP trap in accordance with the manufacturer's instructions (mosquitomagnet.com). Collections were conducted when biting anophelines are most active, i.e., from 17:30 pm-21:30 pm (Rubio-Palis et al. 2009) for three nights per month every two months. SPSS 15.0.1 software (2006) was used for the data analysis.



Relative location of study site, Jabillal, state of Bolívar, Venezuela.

A total of 1,276 anophelines belonging to six species were collected via HLCs, whereas the two MMLP traps caught a total of 597 anophelines representing seven species (Table). *An. darlingi* and *An. nuneztovari* were the most common species collected by both methods; *An. marajoara* was more abundant on humans than in the MMLP catches and *An. oswaldoi* was more frequently found in the MMLP traps than in the HLCs. The analysis of the data showed that the number of mosquitoes of each species collected depended on the method (chi-square = 78.304, $p < 0.05$). Similarly, a one-way ANOVA indicated significant differences between both methods for catching *An. darlingi* ($F = 16.20$, $p = 0.0001$), *An. marajoara* ($F = 7.318$, $p = 0.008$) and for the total number of mosquitoes collected ($F = 7.754$, $p = 0.006$), but not for *An. nuneztovari* ($F = 1.076$, $p = 0.302$).

To quantify the efficiency of the MMLP trap catches compared with the HLC method, ratios were calculated by dividing the log-transformed nightly ($n = 15$) mean catches in the MMLP traps by the mean of the HLCs for each of the two most abundant species and for the total

TABLE

Anopheline species collected on human landing catches and Mosquito Magnet® trap between June 2008-January 2009 (15 nights), Jabillal, state of Bolívar, Venezuela

Species	Mosquitoes caught (n)	
	Landing catches	Mosquito Magnet
Anopheles (Nyssorhynchus) darlingi	641	248
Anopheles (Nyssorhynchus) marajoara	142	11
Anopheles (Nyssorhynchus) nuneztovari	439	277
Anopheles (Nyssorhynchus) oswaldoi	16	34
Anopheles (Nyssorhynchus) strodei	0	1
Anopheles (Nyssorhynchus) triannulatus	2	6
Anopheles (Anopheles) mediopunctatus	1	0
Anopheles (Anopheles) punctimacula	0	1
Not identifiable[a]	35	19
Total	1,276	597

a: due to loss of taxonomic characters.

number of mosquitoes caught, including all species. The confidence limits were calculated based on the variances of these ratios over different months. On average, if all of the species were pooled, the MMLP traps collected only a fraction of the number obtained by HLCs [19%, confidence interval (CI): 1.47]. However, if an analysis for the most abundant species is performed, the relative efficiency of the traps increased and the ratios differed significantly between species. The MMLP trap was more efficient for collecting *An. nuneztovari* (63%, CI: 2.53) than *An. darlingi* (31%, CI: 1.57). There were significant correlations ($p < 0.01$) between the two methods for *An. darlingi* [Pearson correlation (R^2) = 0.65], *An. nuneztovari* ($R^2 = 0.48$) and the total of mosquitoes collected ($R^2 = 0.34$) if the mosquitoes were pooled by hour ($n = 60$), but not for *An. marajoara* ($R^2 = 0.11$, $p = 0.42$).

During the past decade, several studies have been conducted worldwide to evaluate different models of the MM trap for the control and surveillance of mosquitoes, with different degrees of success. For instance, Kitau et al. (2009) showed that the use of MMLP combined with insecticide-treated nets significantly reduced the biting rates of *Culex quinquefasciatus* Say and *Anopheles gambiae* Giles *s.s.* in Tanzania. In contrast, Henderson et al. (2006) could not demonstrate that the continuous operation of the Mosquito Magnet Pro Model in urban and rural areas of Manitoba, Canada, significantly reduced the activity of *Aedes vexans* (Meigen), *Ochlerotatus sticticus* (Meigen) and *Coquillettidia perturbans* (Walker). In general, MM traps are more efficient for mosquito surveillance than CDC light traps (Brown et al. 2008, Xu et al. 2008, Hoel et al. 2009, Hiwat et al. 2011a). Nevertheless, in Latin America the use of MM trap has been limited to surveillance of West Nile virus in the Yucatan Peninsula, Mexico (Farfan-Ale et al. 2009) and was evaluated to collect anophelines in Suriname (Hiwat et al. 2011a, b) and French Guiana (Dusfour et al. 2010). The latter study is based only on six nights of collections and the number of mosquitoes caught was very small; nevertheless, the study showed that the MMLP trap caught more mosquitoes than the CDC light trap, yet only three specimens of the malaria vector *An. darlingi* were caught by the MMLP. Furthermore, the MMLP trap was more efficient for collecting *An. oswaldoi* than HLCs. Similar results were obtained in the present study, in which significantly more malaria vector species (*An. darlingi, An. marajoara* and *An. nuneztovari*) were caught via HLCs than with the MMLP trap, whereas the trap collected approximately twice as many *An. oswaldoi* as the HLC method. The MMLP is more efficient for collecting *An. nuneztovari* in Venezuela than the CDC light trap (Y Rubio-Palis et al., unpublished observations).

There was a significant correlation between the two methods for *An. darlingi* and *An. nuneztovari*; it is probable that the lack of correlation for *An. marajoara* is due to one or more factors, such as the low abundance and not to the trap itself. In fact, it has been shown that the efficiency of trapping methods is affected by mosquito abundance (Lines et al. 1991). It is recommended that the evaluation of the MM trap be continued in other malaria-endemic areas where the abundance of anophelines is higher to obtain a better estimate of the efficiency of the trap for sampling anopheline populations. Another important factor is that *An. darlingi* and *An. marajoara* are more anthropophilic than *An. nuneztovari* and *An. oswaldoi* and, hence, are attracted to more complex combinations of odours (Takken & Knols 1999) than CO_2 and octenol. Similar results were reported by Hiwat et al. (2011a, b), who evaluated different traps (MMLP, CDC, BG Sentinel) baited with CO_2 in relation to HLCs to catch *An. aquasalis* and *An. darlingi*. That study concluded that CO_2 alone is insufficient to attract anthropophilic mosquitoes and emphasised the importance of different studies conducted in Africa to determine the role of human odours in attracting malaria vectors (Jawara et al. 2009).

These preliminary results are encouraging for further investigations using the Mosquito Magnet trap for monitoring the populations of anophelines in the Amazon Basin. In view of the characteristics of the trap, such as its battery operation, use of propane gas to produce CO_2 as an attractant and ease of transport and maintenance, we are currently using the MMLP trap for the entomological surveillance of malaria in remote areas of the Caura River Basin (Y Rubio-Palis et al., unpublished observations).

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