Mosquito larval control with *Bacillus sphaericus*: reduction in adult populations in low-income communities in Nonthaburi Province, Thailand

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ABSTRACT: During 1999 and 2000 several larvicidal treatments of *Bacillus sphaericus* strain 2362 water dispersible granular (WDG) formulations were made at 50 to 200 mg/m\(^2\) in mosquito developmental sites in low-income communities in Nonthaburi Province, Thailand to determine whether larviciding dense populations would result in a noticeable reduction of adult mosquitoes in small treated areas. In the treated area in 1999 (Soi Jumpa), immature populations were suppressed to extremely low levels for extended periods, especially at the higher dosages. This decline in immature populations was followed by a substantial decline in adult mosquitoes. There was a lag of 7 to 14 days post-larval treatments before maximum decline in adults was noted. Adults that emerged prior to treatments survived for 7-14 days or longer, thus no drastic reduction was noted soon after treatments. Despite a slight resurgence in adult mosquitoes during the middle of the experimental period, adult female mosquitoes (over 98% *Cx quinquefasciatus*), remained low during the 5-month period of trials. During the last 2 weeks (17 days post last treatment) of the experimental period, female populations reached the pre-treatment level. During the 2000 tests at Wat Pikul reduction in larvae was 87-98% for 7 weeks after first treatment at 200 mg/m\(^2\), resulting in a reduction of 24 to 73% (2 and 7 days post-treatment respectively) and 87 to 98 (2-6 weeks) in the adults. In the second and third treatments at 50 mg/m\(^2\), larval control and subsequent adult reduction were lower and shorter-lived than at the high dosage, and the fourth treatment at 100 mg/m\(^2\) did not yield a high level of reduction in the larvae (18 to 33%), but reduction of adults was still 80%. The final fifth treatment at 200 mg/m\(^2\) yielded only 18% control of larvae, suggesting tolerance to *B. sphaericus* at this site. It was shown that at both treated sites repeated treatments with a larvicide such as *B. sphaericus* could result in substantial reduction in adult mosquitoes. Vigilance for detection of resistance development should be practiced, as resistance could emerge in certain populations following a few treatments. *Journal of Vector Ecology* 26 (2): 221-231. 2001.

**Keyword Index:** *Culex quinquefasciatus*, *Bacillus sphaericus*, larval control, adult control, Thailand.

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**INTRODUCTION**

Larval control of mosquitoes either by source reduction, use of larvicides or a combination of these, is a preferred method for reducing adult mosquitoes in many areas of the world. In arid regions where the extent of mosquito developmental sites is limited, larval control through the use of chemical and microbial larvicides has been the method of choice. In urbanized areas, larval control is also practiced extensively in both arid and tropical regions, supplemented by other measures used against adult mosquitoes.

In general, it is believed that area-wide control programs of mosquito larvae also result in the control adult mosquito populations that are responsible for annoyance and the transmission of pathogens. The extent and magnitude of such suppressions are not adequately documented, especially in the tropics. Two recent studies allude to the relationship of larvicidal interventions to reductions in abundance or biting rates of adult mosquitoes and the subsequent impact on disease incidence. Barbazan et al. (1998) in studies carried out in Maroua (north Cameroon), showed effective control of anophelines using *Bacillus sphaericus* strain 2362 larvicidal treatments at the rate of 10g/m\(^2\). In this program, the onset of malaria was
delayed by 2 months and a subsequent reduction in the number of malaria cases was noted. In Zanzibar towns, Maxwell et al. (1999), showed that larval control using polystyrene beads in pit latrines and cesspits (supporting Culex quinquefasciatus Say) in combination with mass drug therapy (diethyl carbamazine) reduced the incidence of bancroftian filariasis significantly. In another town, treatment of pit latrines and cesspits with polystyrene beads reduced the adult mosquitoes by about 65%. This level of reduction in adult mosquitoes was deemed sufficient to result in a decline in the incidence of filariasis.

For the past 4 years we have been evaluating formulations of the microbial control agent Bacillus sphaericus strain 2362 against Cx. quinquefasciatus larvae in polluted water sites in several low income communities in Nonthaburi Province, Thailand. Results of these treatments applied to canals and standing water around and under dwellings were reported earlier (Mulla et al. 1997, 1999). In these studies we only reported the impact of treatments on larval populations without reference to the trends of adult mosquito populations, although the residents reported a marked reduction of mosquito adults and their biting activity. The present studies were initiated to elucidate the relationship between larviciding and population trends of adult mosquitoes, where all accessible mosquito developmental sites in small squatter communities were treated with a larvicide. The larvicide used was a new formulation of water dispersible granules (WDG) of B. sphaericus strain 2362 applied to mosquito developmental sites in 3 squatter communities (1 control and 2 treated) in Nonthaburi Province near Bangkok, Thailand. In addition, to assessing the magnitude of larval control, we obtained quantitative information on the abundance and trends of adult mosquitoes on a weekly basis during the test periods using black light traps placed either inside or just outside dwellings in 2 test areas, a treated site and a control.

MATERIALS AND METHODS

These studies were initiated in the beginning of May, 1999 and terminated in December 2000. The tests were carried out during the rainy seasons in the central part of Thailand in both 1999 and 2000 when frequent heavy showers occurred. Two sites, Soi Jumpa and Soi Raevadee in Pak-Kret District (Mulla et al. 1997, 1999) and one new site, Wat Pikul in Bang Yai District in Nonthaburi Province, were selected for these studies. All 3 sites supported heavy Culex (mostly Cx. quinquefasciatus) mosquito development. In the first series of tests from May-October 1999, Soi Raevadee (control) and Soi Jumpa (treated) were selected for the studies. In the second series of tests from September-December 2000, Wat Pikul was subjected to treatments while Soi Jumpa was used as the control.

Soi Raevadee

This site was established as a control in the 1999 studies, with no treatments during the test period. Mosquito developmental sites consisted of wastewater accumulations under, around, and between dwellings. A large canal in this community supported heavy populations of mosquitoes. All stagnant water accumulations and the canal received a great deal of solid wastes (glass, plastics, metal cans, plant waste materials, etc.), which provided protective niches and rich sources of nutrients for the propagation of Cx. quinquefasciatus. Despite the presence of guppies in these mosquito developmental sites, larval populations were quite heavy most of the time. At the outset, this site had lower productivity in terms of mosquito larvae as compared to the treated area (Soi Jumpa) in 1999 (Figure 1). Raevadee community, like most low-income squatter communities, is densely populated (Mulla et al. 2001). The housing was substandard with many homes having no windows, opening on the sides, and floors and doors with large cracks that allowed the ingress and egress of adult mosquitoes. In this area Cx. quinquefasciatus larvae constituted 98-99% of the larvae sampled. The total area of water supporting mosquito production was about 3000m².

Soi Jumpa

This community consisted of some 100 dwellings located about 3 km from Soi Raevadee. There were ample polluted water accumulations from rain and domestic waste water with sewage seepage under, between, and around the dwellings. Large amounts of solid wastes were present in the water. This habitat provided ideal conditions for the propagation of Cx. quinquefasciatus, the dominant mosquito (98-99%). This site was found to support heavier populations of this species than Soi Raevadee (Figure 1). Therefore, the Soi Jumpa site was assigned the treatment regimen under more demanding conditions. Like in Raevadee, the construction of houses was substandard, allowing easy ingress and egress of mosquitoes. The total area of water subjected to treatments was 3600 m².

Wat Pikul

In September, 2000 this site with an extremely high density of immature mosquitoes was selected for treatment while the site at Soi Jumpa with a relatively
lower larval density was used as a control. The two sites were similar in terms of type of housing and density and the level of organic and solid wastes pollution. Wat Pikul, however, had developmental sites for *Cx. gelidus* Theobald and *Mansonia* species in the adjacent fruit garden areas (not treated), which were absent in Soi Jumpa. There were about 200 dwellings at Wat Pikul and in some dwellings as many as nine families (one family per room) occupied the units. The nature and type of mosquito developmental sites were essentially the same as in Soi Jumpa, except as noted above. Wat Pikul supported slightly heavier populations of *Cx. quinquefasciatus* at the start of the experiment than the control site Soi Jumpa (Figure 2). The treated area in Wat Pikul was divided into 7 sites for the purpose of spraying, and the total area of this site subjected to treatments amounted to 4100 m².

**Sampling**

Mosquito larvae and pupae were sampled by the dipper method. Each site in the tests was sampled before treatment and then 2 days and weekly after treatment for determining the trends of larval and pupal populations. Every site was sampled using 20 dips in spots considered to support heavy aggregations of larvae. It was predetermined that some spots regularly supported heavy larval densities and these spots were sampled repeatedly before and after treatments. The contents of the dipper were transferred to a white enamel pan (15 x 30 x 4 cm deep) and the larvae and pupae were counted on the sites and categorized by instars and if they were pupae. After each treatment, as the larval counts resurged in the treated area, the site was re-treated, provided it was accessible or when no heavy rains were falling.

Adult mosquitoes were sampled for one night approximately every week by placing 3 black light traps (6 watt black light tube, 220 volt) in each of the treated and untreated sites. The traps were hung 1.3 m above the floor or ground. The traps were set and activated at 18:00 h turned off at 06:00 h and collected at 8:00 h the next day. To preclude ant predation on mosquitoes, a band of petroleum jelly was applied to the cord hanging the trap. The mosquito collections were brought into the laboratory and counted. Species identification was made under a stereomicroscope. The data are presented in the figures giving the average number (with standard error) of mosquitoes per trap/night at each interval at each site.

**Materials and Treatments**

In 1999 the treatments were made with experimental preparations of a water dispersible granular (WDG) formulation of *B. sphaericus* strain 2362 provided by Abbott Laboratories, N. Chicago IL. (ABG-6491, lot no. 31-077BR 600 ITU/mg and lot no. 32-094 BR 630 ITU/mg). In the September, 2000 tests a commercial VectoLex™ formulation (lot no. 56-809 PG with 650 ITU/mg) was used. This latter product was manufactured in 1999 by Abbott Laboratories and provided by Valent Biosciences Corp. (Libertyville, IL.). Additional quantities of VectoLex™ were obtained from the NW Mosquito and Vector Control District (Corona, California). The products were applied by spraying most of the accessible larval infested waters, which amounted to about 3600 m² in Soi Jumpa treated in 1999 and 4100 m² in Wat Pikul treated in 2000. The required amount of the WDG formulation for each spray tank was mixed with water in a plastic bucket and then poured into a 7-liter compression sprayer filled to capacity. The formulations readily went into a homogeneous suspension made in plastic buckets and poured into spray tanks. The spray tank was pressurized and the bacterial suspension was sprayed over the water surface through a cone nozzle. The nozzle generated a coarse jet stream of spray that could reach over water surfaces 4-5 m away. Since there was standing water under rows of houses, not all of the larval infested areas could be reached with the spray jet. In total, 6 spray tanks (42 liter spray) were used in each treatment to cover the target area in Soi Jumpa in each of the 1999 tests, while 7 tanks (49 liter) of spray were used to treat Wat Pikul in each of the 2000 tests.

In total, 4 treatments were made in Soi Jumpa during the 5 months of the rainy season (May to October 1999). At this treated site, the dosages applied were somewhat on the low side and varied from 72 mg/m² to 115 mg/m² (0.72-1.15 kg/ha). In previous studies we noted that the WDG formulation gave good control of mosquito larvae at the dosage of 100 + mg/m² (Mulla et al. 1999). We employed dosages lower than 100 mg/m² to assess the initial and persistant control of larvae. In the 2000 tests, Soi Jumpa was established as a control site while a new site Wat Pikul (not used before in our studies) was selected as a treated area, because the latter had somewhat heavier larval densities (Figure 2) before *B. sphaericus* treatments were initiated. Adjacent to the study area there were substantial developmental sites for *Cx. gelidus* and *Mansonia* species which added to the adult counts in light traps. In Soi Jumpa vicinity developmental sites for these species were lacking. The Wat Pikul site receiving a total of 5 treatments was treated initially with a high dosage (200 mg/m² or 2.0 kg/ha), to see if higher dosages (at the upper end of label dosage) would provide long-lasting control. This first treatment at Wat Pikul was made on September...
14, 2000, and the subsequent four treatments, two at the low dosage of 50 mg/m² (0.5 kg/ha), one at 100 mg/m² (1.0 kg/ha) and the last at the high dosage of 200 mg/m² were made on October 26, November 16, November 30, and December 8, 2000 respectively. In Wat Pikul 2000 tests, the percent reductions in immatures and adult mosquitoes were calculated by comparing mean post-treatment counts vs. the original pre-treatment counts. In this calculation, we did not consider the population trends in the control area, as in general the mosquito populations increased during the post-treatment period. We believe comparison of post-treatment populations with the pre-treatment in the treated area provide a better indication of the extent of suppression.

RESULTS AND DISCUSSION

Control of Larval Mosquitoes

Soi Jumpa Tests (1999)

Prior to the initiation of the treatments, the total number of larvae (all instars) and pupae per sample was much higher in the Soi Jumpa community (treated) than Soi Raevadee (control). The immature mosquito populations remained at a relatively stable level in Soi Raevadee for about a month during the post-treatment monitoring, then experienced a slight decline for 5 weeks, but began to increase substantially in numbers thereafter. On the other hand, the first treatment with VectoLex™ WDG formulation at 115 mg/m² in Soi Jumpa on May 10, 1999 suppressed the immatures to a very low level from 165 (pre-treatment) to 2/dip (Figure 1). This very low level of immatures prevailed for about 4-5 days post-treatment with a slight resurgence on day 8 (37/dip) post-treatment. On day 11, the site was given a second treatment at the reduced dosage of 93 mg/m². The second treatment suppressed the immature populations to extremely low levels initially (< 1 to 9/dip) with moderate levels (below 25/dip) occurring for up to 28 days post second treatment. From day 35-49 post second treatment there was a slight but sustained resurgence of the immatures, the immatures density reaching 43-60/dip. The site was then retreated at the low dosage of 72 mg/m² (0.72 kg/ha). This treatment depressed the immatures to a mean number of 4/dip but then increased on day 14 to about 50/dip. From day 21-49 post third treatment (at 72 mg/m²), high populations of larvae and pupae were present ranging from 88 to 136 total/dip. Then, the fourth treatment at 114 mg/m² (1.14 kg/ha) was applied. This treatment in this series suppressed populations drastically to 8/dip on day 3 post-treatment, remaining below 40/dip up to 17 days post-treatment, then resurging to high levels (92-113/dip) on days 24-32 post-treatment. During the 5 month test period, treated larval populations in Soi Jumpa never returned to the pre-treatment levels.

The total immature mosquito population trends at the Soi Raevadee control site, however, remained at the pre-treatment level or higher except during the concomitant period of post-second treatment. Soi Raevadee populations declined from a total of 63/dip pre-treatment to about 10/dip during days 28-42 corresponding post-second treatment. The populations began to resurge to the pre-treatment level or higher during the twelve weeks corresponding to the third and fourth treatment periods. For this extended period the densities of immature populations ranged from 67-243/dip.

Wat Pikul Tests (2000)

Prior to treatment, Wat Pikul had a high density of immature mosquitoes, (275+ per dip). The first treatment at the relatively high dosage of 200 mg/m² of VectoLex WDG caused a high level of reduction (> 98%) in immatures. This low density of immatures lasted for 35 days post-treatment (Figure 2). On day 41 post-treatment the immatures resurreded to 60/dip and the level of control dropped to 83%. At this time (day 41 post-treatment), the site was retreated at a lower dosage to see if adequate larval suppression could be sustained.

The second treatment at the low dosage of 50 mg/m², suppressed the immature Cx. quinquefasciatus populations to a very low level (5/dip 2 days and 8/dip 6 days post-treatment). The reduction was 89-98% for a period of 2 weeks. The immature populations then increased (145/dip), and the level of control dropped to 47% at 20 days post-second treatment (Figure 2). The site was given a third treatment (20 days post-second treatment) at the low dosage of 50 mg/m². This treatment gave an initial control of 88% of immatures, but the level of control dropped to 64 and 47% on days 6 and 13 post-treatment respectively (Figure 2). The fourth treatment was then applied at the moderate dosage of 100 mg/m² of VectoLex™ from NWMVCD. Surprisingly, this treatment did not cause much reduction of immatures; the level of reduction was only 35% on day 2 and 13% on day 6 post-treatment. We suspected that the population of Cx. quinquefasciatus at Wat Pikul became somewhat tolerant to B. sphaericus. To test this hypothesis, we made the fifth and last treatment at the original high dosage of 200 mg/m².

The fifth and last treatment (at the high rate of 200 mg/m²) yielded only 18% reduction of immature mosquitoes three days after treatment. The density of
Figure 1. Population trends of mosquito larvae and pupae (predominantly *Cx. quinquefasciatus*) in treated (with *B. spahericus* WDG formulations) and untreated low-income communities, Nonthaburi Province, Thailand. During the 5-month testing period (May-October, 1999), there were 30 episodes of rain amounting to 5-15 mm each.
Figure 2. Population trends of mosquito larvae and pupae (predominantly *Cx. quinquefasciatus*) in treated (with VectoLex WDG formulation) and untreated low-income communities, Nonthaburi Province, Thailand. During the 2.5-month testing period (September-December, 2000), there were 13 episodes of rain amounting to 5-15 mm each.
Figure 3. Impact of larval control using *B. sphaericus* WDG formulation on the abundance of adult mosquitoes (*Cx. quinquefasciatus*) as measured by blacklight traps in low income communities, Nonthaburi Province, Thailand. During the 5-month testing period (May-October, 1999), there were 30 episodes of rain amounting to 5-15 mm each.
Figure 4. Impact of larval control with VectoLex WDG formulation on the abundance of adult mosquitoes (*Cx. quinquefasciatus*) as measured by blacklight traps in low income communities, Nonthaburi Province, Thailand. During the 2.5-month testing period (September-December, 2000), there were 13 episodes of rain amounting to 5-15 mm each.
immatures per dip by instars and stage were 40 (first-second), 153 (third-fourth) and 6.7 (pupae). This high density of immatures, especially that of third and fourth instars, suggests the emergence of tolerance to B. sphaericus in mosquitoes at Wat Pikul after 5 treatments. The nature and magnitude of resistance of this population are not understood, but the evidence signals a warning that in certain locations, specific populations can acquire tolerance to this microbial control agent rather quickly. Further studies on the nature and scope of this tolerance are in progress.

The first treatment at Wat Pikul at the high dosage (200 mg/m²) yielded a high level of immature control (95%+) for extended periods of up to 5 weeks post-treatment. The two subsequent treatments, made at the low dosage of 50 mg/m², each provided lower levels of control, lasting for only 6 to 13 days. The level of control further dropped following the 4th treatment at 100 mg/m². The last treatment at 200 mg/m² (a dosage that gave over 95% control in the first treatment) yielded little or no control. It should be noted that pupal populations were reduced by almost 100% within 2 days after each of the first two treatments rendering 95-98% larval control, however, pupal reduction was not complete in the next three treatments. B. sphaericus toxins do not affect pupae as they do not feed or ingest the toxins. Pupal disappearance is the result of emergence of adults or absence of larvae from becoming pupae. Heavy larval mortality led to the reduction in the pupal population. It appears that the rates of 100-200 mg/m² would be necessary to achieve satisfactory initial and extended control of immatures under conditions as in this study area, but vigilance should be exercised in detecting tolerance after a few treatments in certain developmental sites.

Reduction in Adult Mosquitoes


Prior to the initiation of treatments at Soi Jumpa, the total of male and female mosquitoes collected in light traps was about 6 times higher in the Soi Jumpa treated area (2531 to 3739 total/trap/night) than in the Soi Raevadee control site (291-544/trap/night). Four days after the first B. sphaericus larvalicidal treatment, the adult mosquitoes were suppressed to a very low level (619/trap/night) in the Soi Jumpa treatment area and their populations further declined to 394/trap/night on day 11 post-treatment. The adult population decline continued, with the total number reaching 243, 242 and 177 per trap/night on day 2, 7, and 14 post-second treatment respectively (Figure 3). This low level of adult mosquitoes prevailed for about 2 weeks post-second treatment, but experienced a moderate resurgence (944-1419/trap/night) on days 21-49 post-second treatment. The level of resurgence was again suppressed, although, not as precipitously as before by the third treatment of the larvae at the very low dosage of 72 mg/m². Overall, the total adult mosquito populations prevailed at moderate levels (973-2085/trap/night) for 49 days post third treatment. The adult populations remained at high levels after the 4th larvalicidal treatment at 114mg/m² of VectoLex WDG. The adult collections fluctuated between 1345 and 4117 adults/trap/night.

The adult populations in the Raevadee control site, in contrast to the treated Soi Jumpa site, increased during the 3-4 week after the first treatment period (571-660/trap/night) but declined about a month later. The population remained low for 8 weeks (161-708/trap/night), then resurged to higher levels (ranging from 305 to 4269/trap/night) during the remaining 2 month period of the test (Figure 3). During most of this period of the test, the adult mosquitoes in the control area prevailed at higher numbers than their pre-treatment populations. Toward the end of the test period corresponding to 31-38 days post 4th treatment, the total adult capture was 2-13 times more than the pre-treatment counts in the control site, while no such resurgence was noted in the treated area. There was a substantial increase in adults in the treated area following the fourth treatment. This increase corresponds to the increase in larval density during this period (Figure 1). The adult mosquitoes, especially females, in the treated Soi Jumpa area, reached pre-treatment levels or higher about 31 to 38 days after the fourth treatment when the test was terminated.

During the course of the 5-month studies, Cx. quinquefasciatus constituted over 98-99% of the adult mosquitoes trapped at both sites, Soi Jumpa and Raevadee. A few adults, mostly females, of Armigeres subalbatus Coquillet and Cx. (Lutzia) fuscatus Wiedemann and Mansonia spp. were also trapped occasionally. To gain information on the collection of blood-fed female Cx. quinquefasciatus for future studies we assessed the numbers of blooded females. In this species the number of blood-fed varied from 0.3% to 36% (36% only in one collection) in the 50 collections made in the treated and untreated sites. Most of the collections contained an average of only 3-5% blooded mosquitoes. There were only 4 collections in the treated and 3 collections in the untreated area, which had no blood-fed females.


Following the first larval treatment with VectoLexÒ WDG formulation (200 mg/m²) there was a marked reduction in adult mosquitoes collected by black light.
traps. The reduction in adults was 24 and 73% compared to the pre-treatment counts after 2 and 7 days of the treatment respectively. The decline in adult populations increased and reached 91 and 95%, on days 14 and 28 post-treatment. The reductions in adult collections were 89 and 87% on days 35 and 42 post-treatment respectively (Figure 4). A lag time was noted of about 1-2 weeks after larval treatment before the adult mosquito populations were markedly suppressed following larvicidal treatment. Adult mosquitoes that emerged prior to larval treatment can survive for one to two weeks or longer. Thus, this lag time in adult suppression was expected. Following the second treatment at the low dosage of 50 mg/m², the reduction in adults was 83% one week and 74% two weeks post-treatment.

The reduction in adult populations was somewhat lower following the third treatment (50mg/m²) when compared to the second treatment. The reduction after the third treatment was 60-86%. The reduction in adults after the fourth treatment (100 mg/m²) was 79%, despite the fact that there was a low level of larval control (18-33%) with this treatment (Figure 2). It seems that there is a lag time of 1-2 weeks for resurgence of adult populations following failure or termination of larvicidal treatments. The last larvicidal treatment in this series of tests was made at the high rate of 200 mg/m². This treatment yielded only 18% control of the immatures (Figure 2). Because of this failure of control, adult populations were not trapped after this last treatment. At this point we were convinced that the decreasing efficacy of larviciding was due to the appearance of tolerance to B. sphaericus at this site. Further studies on the rapid emergence of resistance at this site are continuing.

Concomitantly, the adult populations in the untreated Soi Jumapa community remained relatively stable over the entire test period, never declining more than 36% of the original populations, and for the most of the study period increased over the pre-treatment level (Figure 4). In Soi Jumapa, the mosquitoes were for all purposes Cx. quinquefasciatus (over 98%) with few Cx. gelidus trapped during October and November. The proportion of Cx. gelidus in the collections increased as adults of Cx. quinquefasciatus declined due to treatments. In Wat Pikul, however, we collected Cx. gelidus that made up to 7-27% of the collections. This species probably developed in standing water in fruit gardens across the road from the Wat Pikul study site. We collected Cx. gelidus females, mostly without blood, and very few males, in every trap collection, ranging from 28 to 404 per trap/night. Since males were absent, this mosquito is believed to be not propagating in the treated polluted water site. It is hypothesized that the females were flying into the treated site, as we found no Cx. gelidus larvae breeding in the polluted water at Wat Pikul.

These studies illustrate that control of larvae of Cx. quinquefasciatus can result in a marked and sustained reduction in the adult populations within a short period of one to two weeks after the first treatment. This decline in adult mosquitoes was noted by the residents, who experienced reduced host-seeking and biting activity of mosquitoes during most of the treatment period. Residents at Soi Raevadee (control) expressed no such perceptions, except during the 6-week period when the larval and adult populations declined naturally. It should, however, be noted that the very high level of larval control did not result in a correspondingly high level of control of adults. This discrepancy was expected because not all developmental sites of larvae were accessible and thus could not be treated. Likewise the areas treated were not large enough to preclude the movement of adult mosquitoes from outlying untreated areas. Lastly, adults that emerged prior to larval treatments survived for 2 weeks or longer, contributing to the slow decline of adults for a few days following larval treatments. Regardless, 80-98% reductions in female mosquitoes was achieved in both test areas with the application of a larvicide.

We conclude that treatments with laricides even in limited areas can lead to a substantial reduction in the number of active host-seeking adult Cx. quinquefasciatus. Similar larvicidal treatments and larval control efforts reduced anopheline adults (Barbazan et al. 1998) and Cx. quinquefasciatus adults (Maxwell et al. 1999), which resulted in a decline of malaria and bancroftian filariasis respectively. Studies of this nature on other mosquitoes in a variety of habitats are warranted to document the effectiveness of larvicidal programs in suppressing adult mosquitoes.

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