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AN INEXPENSIVE INTERVENTION FOR THE CONTROL OF LARVAL *AEDES AEGYPTI* ASSESSED BY AN IMPROVED METHOD OF SURVEILLANCE AND ANALYSIS

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ABSTRACT. A sampling method coupled with statistical calibration factors was developed to accurately assess the numbers of larvae and pupae of *Aedes aegypti* in large water-storage containers of variable capacities and water levels. *Aedes aegypti* productivity in different types of breeding sites found in an urban study area in central Colombia was assessed and compared. In this study, water-storage tanks and drums were found to comprise 79% of the containers positive for larval *Ae. aegypti,* which contributed to 93 and 92% of the total production of populations of 4th-stage larvae and pupae, respectively. These main breeding sites of *Ae. aegypti* were found at an indoor to outdoor ratio of 2.4:1 and no correlation was found between temporal fluctuation of populations of larval *Ae. aegypti* and monthly rainfall. Netted lids that used inexpensive local materials were designed to prevent oviposition by *Ae. aegypti.* During a 6-month trial period, 56% of inspected containers had netted lids correctly in place. Of these, 78% had no mosquito larvae. Because only 37% of uncovered containers were free of mosquito larvae, a significant difference was demonstrated when these inexpensive mechanical barriers were used ($\chi^2 = 138.7$; $P < 0.001$). These netted lids and the improved methods described to assess the productivity of larval and pupal *Ae. aegypti* in this study are now being used in combination with other strategies to assess and control these populations of dengue virus vectors in the main port city on the Atlantic Coast of Colombia.

KEY WORDS *Aedes aegypti,* mosquito breeding sites, mosquito control, Colombia

INTRODUCTION

Presently, the only available method to decrease the incidence of dengue fever and its severe manifestations, dengue hemorrhagic fever and dengue shock syndrome, is by reducing vector densities through an integrated control program to minimize virus transmission (WHO 1997). In areas at risk for yellow fever and dengue fever, dengue hemorrhagic fever, and dengue shock syndrome, surveillance of *Aedes aegypti* (L.) is routinely performed by the examination of water-holding containers. Currently, the *Stegomyia* house index, container index, and Breteau index are used to assess the risk of dengue virus transmission (PAHO 1994). However, specification of an *Aedes* sp. index below which dengue virus transmission cannot occur has been controversial, and the use of these *Stegomyia* indices for assessing the risk of dengue virus transmission has been questioned because these indices do not give information on container productivity (Tun-Lin et al. 1994). Although enumeration of the entire population of mosquito larvae usually is impractical, the total vector population may be estimated by counting the larval populations in a portion of the vector breeding sites chosen randomly. For this task, nets or dippers have been used (Knight 1964). Surveys of pupal *Ae. aegypti* have been used to assess the abundance and productivity in each type of container (Focks and Chadee 1997). In surveillance programs, adult mosquito productivity may be assessed by selecting a particular mosquito larval stage and a rapid and reliable sampling method to estimate the total numbers of the mosquito larvae in large water-holding containers (e.g., drums and tanks), whereas the total number of mosquito larvae in small containers is assessed by counting. The absolute abundance of 4th-stage larvae of *Ae. aegypti* in 2,000-liter drums could be estimated by counting the number of larvae collected by 1 sweep of the water surface layer in this type of container (Tun-Lin et al. 1994). In Colombia (Tinker and Olano 1993) and elsewhere in Latin America (Marquetti et al. 1996), custom-constructed tanks of different shapes and capacities are the main types of water-storage containers used. In this study, we used the results of a sweep method to derive a new formula to more accurately estimate the numbers of larval and pupal *Ae. aegypti* in water-storage tanks of different volumes and water levels. Numbers of larval and pupal *Ae. aegypti* then were assessed in each type of breeding site found in the town of Puerto Triunfo (Colombia) where dengue virus was found in both the human and mosquito populations (Romero-Vivas et al. 1998, 2000). The efficacy of inexpensive mechanical barriers to prevent oviposition by *Ae. aegypti* in the most productive breeding sites identified in the town also was evaluated.

MATERIALS AND METHODS

Puerto Triunfo is a port situated on the Magdalena River (Departamento Antioquia) at a latitude

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of 5°52′56″N and an altitude of 150 m. During this study, 2,370 people lived in 413 houses and 94, 97, and 91% of the premises were supplied with electricity, piped (tap) water, or were connected to the sewerage system, respectively. Two socioeconomic strata (1 and 2), which were the lowest of the 6 strata defined in Colombia (Alcaldia de Puerto Triunfo, unpublished data), were identified in this town.

Because this survey included both residential and nonresidential properties, the sampling unit was called a premise, which was defined as a building with an independent entrance. Any part of a premise that was under a roof was defined as indoors, whereas any place within a premise that was not covered by a roof (e.g., backyard) was defined as outdoors, as described previously (Chan et al. 1971). The municipality was divided into 3 geographical sections (1, 2, and 3) and each section was further divided in 4 subsections (A, B, C, and D) that contained equal numbers of premises; within each subsection, all the premises were numbered arbitrarily and 10 were selected at random by using numbers generated by computer within the software package EPI INFO (World Health Organization, Geneva, Switzerland). One hundred twenty premises were surveyed monthly; 1 group of 120 was studied for 8 months, and another group of 120 was studied for 4 months.

A general survey was performed monthly from February 1996 to January 1997. The presence or absence of at least 1 larval *Ae. aegypti* was recorded for each container. Up to 5 mosquito larvae were collected from each larvae-positive container for species determination. The types and numbers of potential breeding sites of *Ae. aegypti* were recorded and the dimensions and water-holding capacities of the inspected ground-level tanks, elevated tanks, and drums were determined. The location (outdoors or indoors) of each *Ae. aegypti* larvae–positive container was recorded, as well as whether or not the containers were covered. Daily maximum and minimum temperatures were registered indoors at noon and the daily rainfall (mm) was registered throughout the study period at 0800 h.

Container productivity was assessed from July 1996 to January 1997 in water containers that were positive for larval *Ae. aegypti* during the general larval survey. During this study, only the 4th-stage larvae and pupae were counted. The numbers of larval and pupal *Ae. aegypti* found in each breeding site were recorded in addition to water level, water temperature, pH (pH-sensitive test strips, P4786, Sigma, Dorset, United Kingdom) and the presence of other mosquito species.

The entire population of larvae and pupae of *Ae. aegypti* found in small containers (e.g., tires, cans, flower vases, bottles, and plastic boxes) was removed with a pipette and counted. For these containers, the productivity index was defined as the total number of 4th-stage larvae and pupae divided by the total number of each type of container inspected.

Larvae and pupae of *Ae. aegypti* found in large containers such as drums and tanks were collected by sweeping the water surface layer once with a net (15-cm diameter × 20-cm depth). The productivity index was defined as the estimated total number of larvae or pupae of *Ae. aegypti* divided by the total numbers present in either tanks or drums inspected.

Productivity trials were performed to determine experimentally how the number of larvae or pupae obtained in 1 sweep of a net relates to the actual number in the whole container. These trials were performed in one 220-liter drum and 2 tanks with 1,498-liter (large tank 1) and 446-liter (small tank 2) capacities, respectively. Three water levels (one-third full, two-thirds full, and full) were tested, and 100, 500, and 1,000 4th-stage larvae and 100, 200, and 500 pupae of *Ae. aegypti* were introduced into each container. Ten sweeps were then performed for each test to collect these larvae or pupae at 10-min intervals, and any damaged larvae or pupae were replaced. Linear regression analysis was then used to obtain calibration factors to estimate the amount by which the numbers collected in 1 sweep of the net should be multiplied to give the actual number on the whole container. This calibration factor was then applied to the field measurements made for the productivity larval survey.

In the intervention trial, mechanical barriers (netted lids) were fitted on the most productive breeding sites of *Ae. aegypti* found in the town. These netted lids were designed individually for each water-storage tank. Lids consisted of a wooden frame (1.5 in. × 1.5 in.) treated with a locally used preservative (vareta) that was not known to be toxic, to which a 1-mm^2 fiberglass mesh was secured with 1-in. nails. Frames were then fully coated with white paint to make the surface less attractive to gravid *Ae. aegypti* and to prevent any contamination of water with vareta. A ledge was created by 1-in.-diameter rigid plastic electric-cable tubing that was secured to the inner wall with screws approximately 3 in. below the top of each tank. Gaps between the tubing and the walls of these tanks were then filled with concrete to create a solid gap-free ledge to support these framed lids so that mosquitoes could not enter. The lids for water-storage drums were made of the same fiberglass mesh, but were secured around the side of the drums by strong cloth and elastic. Premise selection for the intervention trial of mechanical barriers was based on the presence of larval- or pupal-positive water containers for at least 5 months of the 8-month general larval study period (February 1996 to September 1996). A follow-up study was performed from November 1996 to the 3rd week of April 1997 to evaluate the effectiveness of these mechanical barriers through weekly inspections to record the presence or absence of 4th-stage larvae and pupae of

Table 1. Total number of inspected containers found with water and larval *Aedes aegypti* in Puerto Triunfo between February 1996 and January 1997.

Category	No. inspected	No. with water (%)	No. larvae-positive (%) (95% CI)
Elevated tanks	286	265 (93)	34 (12) (8–16)
Ground-level tanks	1,470	1,393 (95)	577 (39) (37–42)
Drums	536	493 (91)	198 (37) (34–41)
Tires	354	258 (73)	79 (22) (18–27)
Bottles	2,438	2,152 (88)	7 (0.3) (0.1–0.5)
Vases	74	68 (92)	15 (20) (11–29)
Half-discards[1]	340	317 (93)	28 (8) (5–11)
Discards[2]	140	132 (94)	7 (5) (2–9)
Others[3]	768	578 (75)	85 (11) (9–13)
Total	6,406	5,656 (88)	1,030 (17)

[1] Recycled plastic bottles used for watering animals.
[2] Metal cans and plastic containers considered to be rubbish.
[3] Toys, pans, drawers, or plastic baths.

Ae. aegypti. During these inspections, records were also collected on whether these lids were correctly seated so that no apparent apertures were present around the edges, whether washing activities were being performed at the time of the inspection, and the number of days before each inspection that each container had been washed. Netted lids were not put on containers in the control premises that were surveyed over the same time period.

For comparing the proportions of *Ae. aegypti* larvae and pupae–positive containers, Yates's corrected chi-square test was used. Pearson's product–moment correlation coefficient was used to quantify the association between the monthly rainfall and entomological outcomes. Linear regression analysis was used to estimate calibration factors in the preliminary container trials, assuming approximate normality of the proportion of larvae and pupae recovered. Ninety-five percent confidence intervals were calculated for proportions or for geometric means (GMs) by applying standard methods for means to the logged larval and pupal counts.

RESULTS

During the study of larval *Ae. aegypti,* 226 of 240 studied premises were residential. Occupants of 79 (33%) of these residential premises belonged to the lowest socioeconomic stratum (stratum 1). Total number of inhabitants in the 240 premises surveyed was 1,089, with an average of 5.2 and 4.4 inhabitants per premise in stratum 1 and stratum 2, respectively. Most of these premises were single storey with walls made of wood or brick covered with cement rendering, and the roofs were made of corrugated iron sheeting with open eaves. Windows, if present, were small and without screens or glasses. All of the houses opened directly onto the street. Air wells were present behind each house. The mean temperature during the study period was 29°C, with the highest mean monthly temperature of 30.6°C recorded in August and the lowest mean monthly temperature of 26.1°C recorded in February. The total annual rainfall was 3,842 mm, with the highest monthly rainfalls occurring in August (610 mm), September (530 mm), and October (462 mm).

During the larval survey, 1,440 inspections were performed. In 698 inspections, mosquito larvae were found in at least 1 container (premise index = 48% [PAHO 1994]). Of the total number of 6,406 potential water containers inspected, 5,656 contained water and 1,030 contained larval *Ae. aegypti* (Breteau index = 72; container index = 16% [PAHO 1994]). Ground-level tanks and drums were the most common breeding sites for *Ae. aegypti* (Table 1). The majority (73%) of *Ae. aegypti* larvae–positive premises had only 1 larvae-positive container (range, 1–12 positive containers). Insects of the family Notonectidae were present in 12 of the water-storage containers that did not contain larval *Ae. aegypti,* and 5 containers (all ground-level tanks) also contained catfish. Interestingly, the cemetery was negative for mosquito larvae throughout the surveillance period.

Seventy percent of containers with larval *Ae. aegypti* were ground-level tanks and drums found indoors, whereas 30% were ground-level tanks, drums, and tires located outdoors (indoor to outdoor ratio = 2.4:1). None of these *Ae. aegypti* larvae–positive containers located outside were covered. No significant correlation was found between the number of *Ae. aegypti* larvae–positive containers and the monthly rainfall ($r = 0.16$, df = 10, $P > 0.05$).

A significant difference ($\chi^2 = 75.95$, df = 11, $P < 0.001$) was found in the proportion of mosquito larvae–positive containers between subsections of Puerto Triunfo. Each subsection averaged 86 mosquito larvae–positive containers (range, 56–117). Twenty-two percent (229 of 1,030) of *Ae. aegypti* larvae–positive containers were present in 2 subsections (2A and 2B) located in the central urban area of Puerto Triunfo.

Table 2. Estimated number of 4th-stage larvae and pupae of *Aedes aegypti* in each type of container in Puerto Triunfo from July 1996 to January 1997.

	Larvae					Pupae				
Container type	No. observations	Total 4th-stage larvae	Range	Geometric mean	95% CI	No. observations	Total pupae	Range	Geometric mean	95% CI
Elevated tanks	8	5,176	45–2,268	302	98–931	8	696	8–350	40	13–122
Ground-level tanks	314	138,281	8–2,560	227	199–260	313	28,408	0–1,302	37	31–44
Drums	116	50,311	0–2,685	202	157–259	115	6,785	0–441	26	20–34
Tires	29	8,571	1–1,400	69	32–149	29	2,242	0–501	20	10–39
Half-discards[1]	12	789	4–236	39	19–82	12	284	0–190	6	2–19
Discards[2]	5	350	4–310	10	2–147	5	73	0–69	3	1–32
Others[3]	6	49	3–23	6	3–13	6	9	0–6	2	1–4

[1] Recycled plastic bottles used for watering animals.
[2] Metal cans and plastic containers considered to be rubbish.
[3] Toys, pans, drawers, or plastic baths.

No association was found between the monthly rainfall during the study period and either the number of containers with water (wet containers) or the number of containers with larval *Ae. aegypti*. However, the difference between the maximum monthly number of *Ae. aegypti* larvae–positive containers (February: $n = 127$) and the minimum monthly number (July: $n = 59$) was approximately 2-fold.

Water capacities of elevated tanks and ground-level tanks (homemade of cement), which varied in size from house to house, were recorded; their capacities ranged from 360 to 6,060 liters and 40 to 4,550 liters, respectively. However, 72% of these tanks had capacities of less than 1,000 liters. Seventy-four percent of the drums inspected had water capacities of 220 to 400 liters, but 220-liter drums were used most frequently.

In the experimental productivity trial, significant differences were observed in the numbers of larval *Ae. aegypti* collected from containers that were one-third full or two-thirds full compared to those that were full ($P < 0.001$), and this difference was more marked in the small tank than in the large tank or drum (significant interaction, $P < 0.001$). We estimated the recovery of 4th-stage larvae of *Ae. aegypti* in a single sweep at between 20.6 and 32.7%, depending on the container type and the water level (equation not shown). Also, significant differences were observed in the numbers of pupae of *Ae. aegypti* collected at different water levels ($P < 0.001$) and, independently, from the large tank compared to the small tank or drum ($P < 0.001$). We estimated the recovery of pupae of *Ae. aegypti* at between 31.6 and 50.8%, depending on the container type and water level (equations not shown). These recovery rates were used in practice to correct the productivity counts made by net sweep in the general larval and pupal survey, by estimating the true count in the whole container. We made a pragmatic assessment of whether a container in the field more closely resembled a large tank or a small tank by applying a cutoff of 1,000-liter capacity.

The water containers found to have larvae or pupae of *Ae. aegypti* during 490 inspections performed during the general mosquito larval survey (July 1996 to January 1997) were used for the productivity study. The total numbers of larvae and pupae of *Ae. aegypti* were individually counted during 63 (13%) of these inspections, and from sweep collections in 427 (87%) of these inspections. Most of these *Ae. aegypti* larvae and pupae–positive containers were ground-level tanks, followed by drums and tires, which were located mainly in the backyards (80%) and indoors (60%) (in shade and under a roof), and nearly all of them (98%) were uncovered. The water levels in these tanks and drums were usually two-thirds full for the ground-level tanks (61%) and full for the drums (55%) and elevated tanks (88%). In 47% of these water containers, the water temperature was approximately 26°C (range, 24–30°C). In 99% of these containers, the pH of the water was 7, but in a few of them it was as low as pH 6 or as high as pH 8.

Of the 490 water containers that contained larvae and pupae of *Ae. aegypti,* 15 (3%) also contained larvae of the *Culex coronator* group and *Culex quinquefasciatus* Say, whereas the remaining containers were infested with only *Ae. aegypti.*

The estimated number of 4th-stage larvae of *Ae. aegypti* in all of the water containers inspected was 203,530, with a range of 0–2,685 per container (Table 2). When the GMs were compared, the most productive water containers were found to be elevated tanks (GM = 302) and ground-level tanks (GM = 227), followed by drums (GM = 202) (Table 2). Because their greater abundance, ground-level tanks were estimated to produce almost 3 times more larval *Ae. aegypti* than the drums and approximately 27 times more larvae than the elevated tanks. Ground-level tanks, drums, and tires were estimated to contribute 68, 25, and 4% of all the 4th-stage larvae of *Ae. aegypti,* respectively. No association was found between the monthly 4th-stage larvae productivity and rainfall ($r = 0.26$, P

Table 3. Numbers (%) of inspections when the intervention water containers were covered or uncovered with the netted lids and were positive or negative for the presence of larval *Aedes aegypti.*

	Test containers		Control containers,
	Covered	Uncovered	uncovered
Larvae-positive	115 (22%)	300 (74%)	211 (63%)
Larvae-negative	401 (78%)	105 (26%)	126 (37%)

> 0.05), and no significant differences were found in the estimated numbers of 4th-stage larvae of *Ae. aegypti* in the premises studied in the different subsections of Puerto Triunfo ($\chi^2 = 18.07$, df = 11, $P > 0.05$).

The total estimated number of pupal *Ae. aegypti* in the water containers inspected was 38,512, with a range of 0–1,302 per container. When the geometric mean numbers of pupae of *Ae. aegypti* were compared, elevated tanks (GM = 40), ground level tanks (GM = 37), and drums (GM = 26) were the most productive water containers (Table 2). Because of their greater abundance, ground-level tanks were estimated to produce 4 times more pupae of *Ae. aegypti* than drums, 13 times more pupae than tires, and 41 times more pupae than elevated tanks. Ground-level tanks, drums, and tires contributed 73, 18, and 6% of all the total estimated numbers of pupae, respectively. No association was found between the estimated monthly numbers of pupae of *Ae. aegypti* collected and rainfall ($r = -0.25$, $P > 0.05$), and no significant differences were found in the estimated numbers of pupae collected from premises in the different subsections of Puerto Triunfo ($\chi^2 = 14.56$, df = 11, $P > 0.05$). All of the most productive water containers were uncovered and 68% of them were located indoors.

In the intervention study, 25 ground-level tanks, 12 drums, and 3 elevated tanks that contained larval *Ae. aegypti* for at least 5 months of the 8-month period of the general larval survey (February to September 1996) were selected to study the effectiveness of simple netted lids to prevent oviposition. These water containers were located in 22 premises distributed throughout the town. Control (uncovered) containers included 9 ground-level tanks, 4 drums, and 2 elevated tanks that were located in 11 premises (1 control drum was removed during week 16 of this study).

Weekly inspections were made of each of these water containers over a period of 23 wk. These lids were found to be closed (correctly placed with no gaps) on 56% (516 of 921) of the inspections. However, on 35% of the inspections, lids had been removed to perform washing activities (washing clothes, dishes, and so on) and on 1% of inspections the containers were found to be dry. Of the correctly covered containers, 78% (401 of 516) contained no larval *Ae. aegypti* (Table 3). No larval *Ae. aegypti* were found on 37% (126 of 337) and 26% (105 of 405) of the inspections of either the control (uncovered) containers or the test containers that were found to be uncovered, respectively. Significant differences ($\chi^2 = 138.7$, $P < 0.001$) were observed between covered test containers vs. control containers. Water containers that were uncovered because of washing activities were negative for larval *Ae. aegypti* on 76% of the inspections and, therefore, no significant differences were demonstrated between this group and the covered water containers ($\chi^2 = 0.01$, $P = 0.92$). No significant difference was found between the percentage of *Ae. aegypti* larvae–positive containers in the intervention group (50 of 266, 19%) and in the control group (33 of 144, 23%) ($\chi^2 = 0.74$, $P > 0.05$) when the containers had been cleaned within 7 days before the inspection. However, significant differences were found between the intervention group and control group when these water containers had been cleaned either between 7 and 14 days before the inspection (intervention group: 270 of 499, 54% vs. control group: 145 of 155, 94%; $\chi^2 = 77.64$, $P < 0.001$) or when they had not been cleaned for more than 14 days (test group: 95 of 156, 61% vs. control group: 32 of 37, 87%; $\chi^2 = 7.6$, $P = 0.005$).

DISCUSSION

In this study, tanks, drums, and tires were found to be the most abundant breeding sites for *Ae. aegypti* in Puerto Triunfo. Similar observations were made in other parts of Colombia and Latin America (Tidwell et al. 1990, Tinker and Olano 1993, Kroeger et al. 1995, Fernandez et al. 1998). Although large numbers of bottles (predominantly soft-drink bottles) containing water were found throughout Puerto Triunfo, their contribution to the total number of *Ae. aegypti* larvae–positive containers was very small (0.6%) compared with either the ground-level tanks (56%), drums (19%), other containers (8%), or tires (8%). This was probably due to the weekly collection of these soft-drink bottles for recycling by the soft-drink company. Few discarded containers were found during this study, since the streets in Puerto Triunfo were cleaned daily and the garbage was collected weekly.

Cemeteries can be important breeding sites for *Ae. aegypti,* such as observed in cemetery vases in Caracas (Venezuela) (Barrera et al. 1979), and in cement vases in cemeteries in Manila (Philippines) (Schultz 1989). However, the cemetery in Puerto Triunfo did not provide breeding sites for *Ae. aegypti* because flowers pots were seldom present and when they were brought to the cemetery, they were filled with sand by the cemetery keeper.

Interestingly, the ground-level tank that was present in the cemetery was infested with insects of the family Notonectidae rather than *Ae. aegypti.* Predation of notonectids on larvae of anopheline, culicine, and aedine mosquitoes has been demonstrated under laboratory conditions (Wattal et al. 1996). Although members of this family could be tested for their ability to control *Ae. aegypti* in this town, the people of Puerto Triunfo would probably object to the use of these insects (or fish) in their domestic water-storage containers. These insects also flew away when the water in these tanks was disturbed, and, therefore, these containers would have to be covered to prevent their escape.

Numbers of larval *Ae. aegypti* did not follow monthly rainfall patterns and marked seasonal fluctuations were not observed in their numbers. This could be because larval *Ae. aegypti* were mainly (78%) found in actively used permanent water-storage containers (ground-level tanks, drums, and elevated tanks) that were predominantly found indoors and uncovered (90%) for an indoor to outdoor ratio of 2.4:1, as also was reported in a study area in Thailand where the most important breeding sites for *Ae. aegypti* were also reported to be domestic storage containers (earthenware, ceramic, or cement jars), and no association was found between the numbers of *Ae. aegypti* larvae–positive containers and rainfall (Sheppard et al. 1969).

Estimation of productivity of *Ae. aegypti* was based upon the abundance of 4th-stage larvae and pupae in each type of water container and their probability of contributing a proportional number of adult *Ae. aegypti* because density-dependent mortality in these mosquito stages has been suggested to be unimportant (Service 1992). The daily emergence of adult *Ae. aegypti* also has been estimated from the numbers of pupae collected in USA and Trinidad, because only a low mortality rate was assumed to occur during the development from pupal to adult stages (Focks et al. 1981, Focks and Chadee 1997).

A sweep net sample of larvae and pupae of *Ae. aegypti* in large water containers could estimate numbers even when their populations were very small. Sweeping also helped to avoid the biased counts obtained when aggregations of mosquito larvae were present, as found when the sampling was performed by dipping (Service 1993). At the water temperature registered in the *Ae. aegypti* larvae–positive containers in Puerto Triunfo (24–30°C), a high recovery of 4th-stage larvae would be expected to be attained by sweeping the water surface of these water-storage containers. At water temperatures below 24°C, larvae of *Ae. aegypti* spend long periods of time at the bottom of water containers, which would, therefore, affect their recovery by this sampling method (Tun-Lin et al. 1994). However, we found significant differences in the percentage of 4th-stage larvae of *Ae. aegypti* recovered with water levels at one-third full and full. When the water level in the large tank and drum was full, the recovery of the mosquito larvae was reduced because they could migrate to the bottom of these tall containers. Although a wider variety of tanks (40- to 4,550-liter capacities) was encountered in Puerto Triunfo than were used in experimental productivity trial, the results might be further validated by taking a sample of containers from homes and comparing single-sweep with whole-container productivity (as is being done in an on-going trial).

The use of mechanical barriers (plastic screens and aluminum lids) on domestic water containers, providing that no gaps were present that allowed access of gravid female mosquitoes, also was shown to prevent oviposition by *Ae. aegypti* in Thailand (Kittayapong and Strickman 1993, Strickman and Kittayapong 1993). Because ground-level tanks and drums were found to have the highest abundance and productivity of *Ae. aegypti,* the control of these breeding sites in Puerto Triunfo would contribute to a reduction of 93 and 92% in the total production of 4th-stage larvae and pupae of *Ae. aegypti,* respectively. The lids were designed for each water-storage container by using locally available (inexpensive) materials at a cost of only 3% (drums) and 6% (tanks) of the minimal monthly salary in Colombia in 1996. The design of mosquito-proof water tanks and drums, including improved mechanical barriers (use of fiberglass), together with our method for estimating productivity of *Ae. aegypti* in these different types of water-storage containers, currently are being tested in a surveillance and control project in Barranquilla (major international port on the Atlantic Coast of Colombia), which is a hyperendemic area for the circulation of dengue viruses.

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