Journal of the American Mosquito Control Association, 20(4):365–369, 2004

SUBSOIL DRAIN SUMPS ARE A KEY CONTAINER FOR *AEDES AEGYPTI* IN CAIRNS, AUSTRALIA

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ABSTRACT. The contribution of subterranean drain sumps to pupal and adult populations of *Aedes aegypti* is reported for the 1st time in Cairns, Australia. Pupal surveys were used to quantify the relative contribution of drain sumps to the total population of *Ae. aegypti* by concurrent survey of sump and water-bearing containers in yards of inner-city premises. A total of 854 mosquito pupae were collected, predominantly *Ae. aegypti* and *Culex quinquefasciatus* (26.3 and 69.8%, respectively). Drain sumps provided a relatively uncommon (n = 4) but productive source for pupal *Ae. aegypti,* producing 14.7% of the combined yard and drain sump population. Drain sumps in inner-city Cairns most commonly occurred in parking lots (52.6%). Subsequently, a sticky emergent adult trap (SEAT) was developed to provide a pragmatic method to assess production of *Ae. aegypti* by drain sumps. A total of 866 adult mosquitoes were trapped from 162 drain sumps over a 48-h exposure period, comprising *Ae. aegypti* and *Cx. quinquefasciatus* (21 and 79%, respectively). Advantages of the SEAT are an ability to rapidly count, identify, and sex mosquitoes and to provide specimens for molecular analysis where necessary. The treatment of water-bearing drain sumps is a critical element of control campaigns against *Ae. aegypti.*

KEY WORDS *Aedes aegypti,* dengue, surveillance, sticky trap, Australia

INTRODUCTION

Dengue is an emerging viral disease throughout the world (Mackenzie et al. 2001). In Australia, dengue is restricted by the distribution of the vector *Aedes aegypti* (L.) to northern Queensland (Sinclair 1992). Dengue fever epidemics only occur after the importation of virus in infected travellers. Epidemics have become increasingly frequent in Queensland during the past decade, have included all serotypes, and have necessitated the revision of control strategies (Ritchie et al. 2002a, Hanna et al. 2003). Dengue control campaigns traditionally target the removal or treatment of water-bearing containers in yards that provide breeding sites for *Ae. aegypti,* for example, discarded tires, pot plant bases, rainwater tanks, domestic rubbish, fallen palm fronds, and bromeliad leaf axils (Kay et al. 1987). However, covert, difficult to treat containers also provide significant breeding sites for *Ae. aegypti* in northern Queensland, including elevated roof gutters in the city of Cairns (Montgomery and Ritchie 2002) and subterranean sites such as mine shafts, service pits, and wells in drier parts of the state (Russell et al. 1996, 1997; Kay et al. 2000a). Subterranean sites are often not sampled because of logistic problems. Deep subterranean sites require specialized sampling equipment to collect larvae, for example, funnel traps (Russell and Kay 1999) or plankton nets (Ritchie et al. 2002b).

"Drain sumps" is a generic term used here to describe any subsoil drainage device that collects surface water runoff before discharge into roadside drains. A common misconception is that drain sumps are specifically installed to act as sediment traps to collect debris. Drain sumps are not of uniform dimensions or manufacture. Typically, they are situated at low points in parking lots and yards, or below downspouts from roof guttering, but rarely occur in residential yards. As a by-product of their installation, water may pool in the bottom of a drain sump whenever a void is formed in the pit below the bottom of the lowest pipe (Fig. 1A). Survey data by a specialized dengue vector control staff (Hanna et al. 2001) indicated that drain sumps were productive mosquito breeding sites, particularly in inner-city Cairns, where they are common in the parking lots of hotels and businesses. For example, 21% of drain sumps (n = 109) surveyed in inner-city Cairns between October 1999 and July 2002 contained mosquito larvae, whereas only 8% of 224 drain sumps surveyed elsewhere in northern Queensland were positive. Drain sumps in inner-city Cairns have provided as much as 26.2% (n = 44) of all detected mosquito breeding sites during a dengue incursion response in October 2001 (Walsh, unpublished data). However, the rapid response required to treat affected areas during dengue epidemics does not provide an opportunity to quantify larval or pupal numbers of *Ae. aegypti* in drain sumps.

The aims of our surveys were to quantify the pupal productivity of drain sumps in inner-city Cairns because pupal surveys more accurately measure density of adult *Ae. aegypti* than traditional larval indices and are more appropriate for assessing dengue risk and directing control operations (Focks and Chadee 1997), and to develop a practical method to quantify mosquito production in drain sumps.

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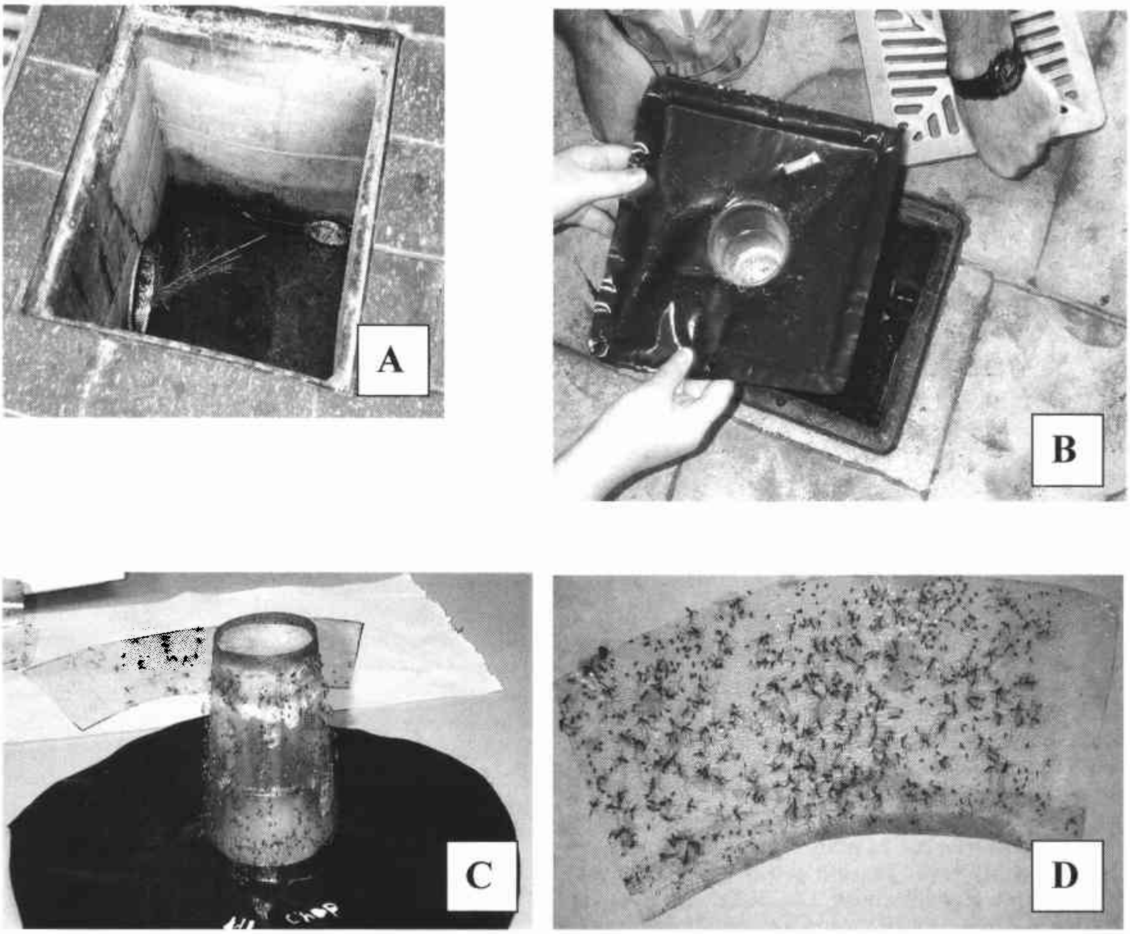

Fig. 1. Elements of the sticky emergent adult trap (SEAT). (A) Drain sump, holding water. (B) Disposable plastic cup is pushed into black plastic cover for drain sump (black plastic is placed under drain sump grill). The outside surface of cup is fitted with a plastic wrap-around template coated with isobutylene adhesive. (C) Cup is cut out from black plastic cover and transported to laboratory. (D) Unfurled plastic template ready for examination of specimens under stereomicroscope.

MATERIALS AND METHODS

Cairns (16°55′S, 145°46′E) is a tropical, coastal city with a strong tourism industry. Inner-city properties are a mixture of detached dwellings, commercial premises, and modern resort-style accommodation. Surveys were conducted for 2 consecutive years in the late dry season (August–November 2001 and 2002), before drain sumps would be flushed out by sustained wet-season rainfall.

Pupal surveys of drain sumps and yards: Concurrent surveys of drain sumps and yards were conducted to establish the relative productivity of drain sumps to the total population of *Ae. aegypti* by pupal counts (Focks and Chadee 1997). Pupae in drain sumps were sampled by a "vortex technique." This involved the initial removal of any substantial leaf litter or debris, then stirring the sump contents 10 times with a 30-cm ruler to create a vortex, then quickly dipping through the central water column with a small aquarium net (Second Nature® SoftNet®-5, Tetra Sales USA, Blacksburg, VA). The process was replicated 3 times per sump. Calibration trials in a standard-sized drain sump pit (21 × 21 × 26 cm; Everhard rainwater collection/distribution pit, Everhard Industries®, Geebung, Queensland, Australia) recaptured similarly high percentages of pupal *Ae. aegypti* from 3 liters of clean and silt-laden water (n = 10, mean ± SD = 81 ± 12% and 82 ± 12%, respectively). Sumps with minimal water were emptied into sample jars by using a turkey baster. The volume of water in each drain sump was estimated by measuring the water depth and surface area of the sump at ground level. Pupae were counted from surface containers, with the exception of very large items, where subsamples were obtained by pouring the water from the container through the small aquarium net. Rep-

Table 1. Contribution of drain sumps to the standing crops of mosquitoes in Cairns inner-city properties (n = 100) during November 2001.

	Containers with larvae or pupae (n = 66)			Drain sumps with larvae or pupae (n = 18)			
Species	No. containers with pupae	Total no. pupae	Mean (± SD) pupae/container	No. with pupae	Total pupae	Mean (± SD) pupae/sump	Total number of pupae from drain sumps (%)
Aedes aegypti	25	225	9.0 (9.5)	4	33[1]	8.3 (7.4)	14.7
Culex quinquefasciatus	20	596	29.8 (45.5)	9	252[1]	27.9 (39.2)	42.3
Ochlerotatus notoscriptus	5	33	6.6 (7.5)	0	0	0	0
Total	50	854		13	285		33.4

[1] Estimated by using correction for sampling efficiency of 81%.

resentative samples of mosquito larvae and pupae were collected and larvae were identified in the laboratory.

Adult surveys from drain sumps: Adult mosquitoes were captured by using a sticky emergent adult trap (SEAT), similar in principle to the method used to sample service pits (Kay et al. 2000b) and subsequently modified to sample inadequately screened rainwater tanks (Ritchie et al. 2002b). The SEAT (Figs. 1B–1D) consisted of a black plastic sheet placed under, and secured by, the weight of the pit grill. The bottom of a clear plastic, disposable cup (250 ml) was replaced with a fine-mesh (1.0 × 0.5-mm-aperture) screen. The full depth of the cup was inserted through the middle of the plastic sheet to form an airtight seal. A clear plastic template coated with an isobutylene adhesive (Bangs et al. 2001) was secured to the outside of the cup and plastic cover by using a single staple. The SEAT was installed over the drain sump for 48 h (the approximate period for any pupae present to emerge as adults) to estimate pupal numbers and any resident adults. The replacement of the end of the plastic cup with a fine-mesh screen was necessary to maintain the drainage capacity of the drain sump during the sampling period. The adhesive strip was returned to the laboratory for processing. Calibration trials captured 88 ± 15% (n = 6) of adult *Ae. aegypti* in 48 h from 10 and 20 pupae, respectively, placed inside small and large sumps.

RESULTS

Pupal surveys—combined yard and drain sump

Environmental conditions during the pupal survey (October 29–November 6, 2001) were no rainfall, a mean daily temperature of 26.3°C, a daily mean of 9.3 h of sunshine, and a mean daily evaporation rate of 7.44 mm. Corresponding environmental conditions for the preceding 4 wk (October 1–28, 2001) were 52.6 mm, 25.1°C, 9.3 h, and 7.02 mm, respectively. These conditions were favorable for the retention of water in yard containers and drain sumps and subsequent production of pupal *Ae. aegypti.* A total of 854 mosquito pupae were sampled from 66 breeding sites on 100 properties. *Aedes aegypti, Culex quinquefasciatus* Say, and *Ochlerotatus notoscriptus* (Skuse) comprised 26.3, 69.8, and 3.9% of the total pupal population, respectively.

A total of 285 pupae were collected from 18 water-bearing drain sumps during this survey (Table 1). Sumps with pupae were relatively common (n = 13) and productive sites, producing 33.4% of the combined drain-sump and yard-survey pupal population. A significant proportion of the standing crop of *Ae. aegypti* originated from drain sumps (n = 4, 14.7%). Additional drain sumps (n = 9) were a productive source of pupal *Cx. quinquefasciatus* (42.3%). Only 1 drain sump contained more than 1 species (inferred from larval identification). Based on a sex ratio of 1:1, pupae from each positive drain sump produced a mean of 4 adult female *Ae. aegypti* and 14 adult female *Cx. quinquefasciatus* per day, respectively.

Drain sumps varied in dimensions and volume of water retained (mean 27.1 liters, range 500 ml to 328.4 liters). The majority of positive drain sumps were on commercial premises (83.3%), with a slight majority of positive sumps (52.6%) in commercial parking lots.

Adult SEAT survey

Environmental conditions during the survey (August 28–September 6, 2002) were 17 mm of rain, a mean daily temperature of 22.0°C, a daily mean of 7.8 h of sunshine, and a mean daily evaporation rate of 6.25 mm. Corresponding environmental conditions for the preceding 4 wk (August 1–28, 2002) were 3.4 mm, 21.4°C, 8.9 h, and 5.9 mm, respectively. These environmental conditions enabled the identification of those drain sumps capable of retaining water during relatively dry periods.

A total of 162 drain sumps within 33 properties (Table 2) captured 866 adult mosquitoes, comprised

Table 2. Mosquito collections from sticky emergent adult traps in drain sumps (n = 162, within 33 properties) over 48 h in Cairns.

Species	No. males	No. females	% all sumps positive for adults	% wet sumps positive for adults	Mean no. adults/sump/day (± SD)
Aedes aegypti	90[1]	92[1]	11.0	29.2	6.0 (5.7)
Culex quinquefasciatus	352[1]	332[1]	9.5	24.2	22.8 (22.3)
Total	442	424			

[1] Estimated by using correction for trap efficiency of 88%.

of *Ae. aegypti* and *Cx. quinquefasciatus* (21 and 79%, respectively). The majority (n = 100, 61.7%) of drain sumps were dry at the time of survey. Half of the drain sumps holding water (n = 31, 19.1% of all sumps) were positive for adults. A mean of 4.9 drain sumps per property (range 1–20) provided a mean of 1 drain sump per property positive for mosquitoes. Based on a sex ratio of 1:1, each positive drain sump produced a mean of 3 adult female *Ae. aegypti* and 11.4 adult female *Cx. quinquefasciatus* per day, respectively.

DISCUSSION

This is the 1st quantitative assessment of the contribution of drain sumps to the pupal populations of domestic mosquitoes in Australia. Drain sumps with breeding mosquitoes were relatively uncommon yet productive sites for *Ae. aegypti* in the dry season, producing 14.7% of the standing crop of pupae. Therefore, significant sources of *Ae. aegypti* can be missed during traditional source-reduction operations. Failure to treat these sites would compromise the efficacy of control operations around dengue case contact points during an epidemic.

Drain sumps with large amounts of water have the capacity to be key containers, that is, produce disproportionate numbers of *Ae. aegypti* (Tun-Lin et al. 1995). We believe the pupal survey underestimated the productivity of sumps for 2 reasons. First, during the pupal survey, 4 additional drain sumps were positive for larval *Ae. aegypti* but contained no pupae. Delaying the survey by a few days would have allowed time for pupation, increasing the number of sumps positive for *Ae. aegypti* and greatly increased pupal counts. Therefore, this underestimate is a reflection of the timing of the survey after egg hatch from recent rain. Second, the large number of drain sumps exclusively breeding *Cx. quinquefasciatus* (n = 9) at the time of survey may indicate additional potential sites for breeding by *Ae. aegypti* at different times of the season. In only 1 instance did a drain sump test positive for both species. The number of drain sumps that test positive for *Ae. aegypti* may vary greatly, following fluctuations in water quality throughout the year.

The SEAT provided a practical method for sampling a logistically difficult site. The SEATs are cheap and quickly assembled and, therefore, well suited for deployment as an operational surveillance tool. An additional advantage is that they provide more accurate data (species, sex, and number) on the productivity of sites than other methods. Adult mosquitoes within the drain sump pit are attracted to the light transmitted through the clear plastic cup and subsequently become trapped on the adhesive. In drain sumps with high densities of pupae, the SEAT will underestimate total populations because of size constraints of the adhesive strip. These traps also have the ability to sample flooded drainage pipes that may be associated with flooded or dry drain sumps. The SEAT provides another use for sticky isobutylene panels. This technique has proven successful for sampling rainwater tanks and subterranean sites (Russell et al. 2002) and as an adjuvant to an ovitrap (Ritchie et al. 2003, 2004).

Relevant public health legislation has a provision for appropriate local and state government officers to penalize any instances of mosquito breeding on private property. However, the current policy is to seek compliance through education. Some drain sumps identified by these surveys as perennial mosquito breeding sites (after repeated visits from Queensland Health vector control staff) have been rectified permanently by the proprietor by filling the sump void with concrete. In the short term, problem drain sumps can be treated with *S*-methoprene products or treated with outdoor, insect surface sprays (Ritchie et al. 2001). We are communicating with the industry representative bodies to ensure drain sump voids are removed at the installation stage. Indeed, the relevant Australian building code was recently amended (Anonymous 2003) to state that "Inlet pits in locations subject to dengue fever borne by mosquitoes shall be without a sump and be self-draining."

ACKNOWLEDGMENTS

We are indebted to the residents of Cairns who kindly permitted inspections of yards. This study was funded in part by a Queensland Arbovirus Advisory Committee (Queensland Health) grant.

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