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CONTROL OF MOSQUITOES IN CATCH BASINS IN CONNECTICUT WITH *BACILLUS THURINGIENSIS ISRAELENSIS*, *BACILLUS SPHAERICUS*, AND SPINOSAD

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ABSTRACT. Catch basins are a major source of *Culex pipiens pipiens*, *Cx. restuans*, and *Aedes japonicus* in northeastern USA. VectoBac® CG (*Bacillus thuringiensis israelensis* [*Bti*]), VectoLex® CG (*Bacillus sphaericus* [*Bs*]), and VectoBac® 12AS (*Bti*), each applied at maximum label rate of 1.8 g, 1.8 g, and 0.193 ml per catch basin, respectively, significantly reduced the numbers of larvae for 1 wk. The dosages on the labels for treatment of mosquito larvae in catch basins, where mosquito breeding is continuous, are not adequate for providing long-term control in the northeastern USA without the need for frequent retreatment. When applied at 3 times the maximum label rate, VectoLex CG, VectoBac 12AS, and VectoBac CG significantly reduced the numbers of larvae for 5, 4, and 2 wk, respectively. A single application of VectoMax™ WSP (*Bti* + *Bs*) (1 pouch containing 10 g) per catch basin significantly reduced the numbers of 3rd and 4th instars and healthy pupae in catch basins in 2008, but numbers of 3rd and 4th instars in treated catch basins at 21 days after treatment had increased to 40% of the numbers in untreated catch basins. A 2nd treatment of 1 pouch per catch basin reduced the numbers of 3rd and 4th instars and healthy pupae to near zero for the next 4 wk, into the middle of September 2008. In 2009, VectoMax applied as 1 pouch per catch basin on July 1 and again on August 18 significantly reduced the numbers of healthy pupae throughout the summer until the end of September. A 2nd application of VectoMax to catch basins is likely needed during summer, when rainfall averages 13.7 in. (~34.25 cm) during June through September, to keep the numbers of *Culex* and *Ae. japonicus* significantly reduced to lower risk of human exposure to West Nile virus. The application of 1 Natular™ XRT tablet, each weighing approximately 40.5 g (6.25% spinosad), to individual catch basins in 2009 significantly reduced the total numbers of larvae for 5 wk.

KEY WORDS Catch basins, *Bacillus thuringiensis israelensis*, *Bacillus sphaericus*, *Culex pipiens*, *Aedes japonicus*

INTRODUCTION

Bacillus thuringiensis (Berliner) serovariety *israelensis* de Barjac (*Bti*) and *B. sphaericus* Meyer and Neide (*Bs*) (Ahmed et al. 2007 has proposed the transfer of *B. sphaericus* to *Lysinibacillus sphaericus*) are the 2 most commonly used microbial pathogens for control of larval mosquitoes (Lacey 2007). Larvae are killed when they ingest one or both of the crystalline toxins of these bacteria. Efficacy of one or both of these biological control agents applied with different formulations has been reported for a variety of larval mosquito species and habitats, including *Culex* species developing in catch basins (Siegel and Novak 1997, 1999), but their efficacies in controlling larvae have not been evaluated in catch basins in the northeastern USA. Another product that is naturally derived and that has been registered for control of mosquitoes is spinosad, which is a mixture of 2 neurotoxins produced during the fermentation of *Saccharopolyspora spinosa* Mertz and Yao (Hertlein et al. 2010). Spinosad has been reported to kill *Culex* larvae, including *Culex pipiens* L., in laboratory and field studies (Cetin et al. 2005, Romi et al. 2006, Hertlein et al. 2010).

For more than 100 years mosquitoes have been known to develop in collections of storm water in catch basins in the USA (Harbison et al. 2010). *Culex pipiens pipiens* L. and *Cx. restuans* Theobald are important in the transmission of West Nile virus (WNV) in urban areas of the northeastern USA (Andreadis et al. 2001b) and develop to adulthood in relatively large numbers in catch basins (Anderson et al. 2006). Thousands of catch basins have been constructed in cities in Connecticut, where populations of *Cx. p. pipiens* and to a lesser extent *Cx. restuans* are relatively abundant. The newly established Asian species, *Aedes japonicus* (Theobald), also develops in catch basins (Andreadis et al. 2001a, Andreadis and Wolfe 2010). Application of effective insecticides in a timely manner to catch basins in cities will reduce the numbers of adult mosquitoes and reduce risk of the transmission of WNV in urban areas in the northeastern USA.

Stratford, CT, with a population of 49,000, is located adjacent to the Housatonic River where it flows into Long Island Sound. West Nile virus has been isolated from mosquitoes or birds annually in Stratford and other locations in Connecticut since 1999 (Andreadis et al. 2004).

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Table 1. Treatment schedule and quantities of VectoBac® CG, VectoLex® CG, VectoBac® 12AS, and VectoMax™ WSP used per catch basin, Stratford, CT, 2008.

Date product applied	Quantities of each product applied (potency in International Units applied)			
	VectoBac CG (*Bti*)	VectoLex CG (*Bs*)	VectoBac 12AS (*Bti*)	VectoMax WSP (*Bs* + *Bti*)
June 30, 2008	1.8 g (360,000)	1.8 g (90,000)	0.193 ml (231,600)	Not done
July 28, 2008	1.8 g (360,000)	1.8 g (90,000)	0.193 ml (231,600)	Not done
August 1, 2008	Not done	Not done	Not done	10 g (500,000 *Bs*)
August 18, 2008	5.4 g (1,080,000)	5.4 g (278,000)	0.579 ml (694,800)	Not done
August 22, 2008	Not done	Not done	Not done	10 g (500,000 *Bs*)

Hundreds of isolations of WNV have been made in Vero cells from *Cx. p. pipiens* Andreadis et al. 2004, Anderson et al. 2006). Fifty-two persons were identified with WNV infections from 2000 to 2006 in Connecticut, and many lived within 25 miles (40.2 km) of Stratford (Nelson et al. 2007). We report the effectiveness of *Bti*, *Bs*, and spinosad in controlling juvenile mosquitoes developing in catch basins in Stratford, CT, during the summers of 2008 and 2009.

MATERIALS AND METHODS

Treatments

The City of Stratford had purchased 3 commercial products in 2008 for mosquito control from Valent Biosciences, Libertyville, IL. We agreed to evaluate the efficacy of these products in catch basins along with a new formulation, VectoMax™ WSP, developed by Valent Biosciences. We also tested another natural product in 2009, Natular™ XRT, sold by Clarke Mosquito Control, Roselle, IL. Catch basins used in these experiments receive both surface inflow from street runoff and lateral flow-through within the city of Stratford. Reservoir depth in catch basins was variable, ranging from less than an inch (2.5 cm) to about 12 in. (30.5 cm).

2008 experiments

Test materials and experimental design: The formulations tested were VectoBac® CG (*Bti* granular), VectoLex® CG (*Bs*), VectoBac® 12AS (*Bti*, aqueous suspension), and VectoMax WSP (*Bti* + *Bs*, water soluble pouch; Valent Biosciences, Libertyville, IL). The 1st 3 products were applied in a randomized block design with 9 replicates to catch basins at the maximum label rate (VectoBac CG, 1.8 g per catch basin; VectoLex CG, 1.8 g per catch basin; and VectoBac 12 AS, 0.193 ml per catch basin) on June 30 and July 28 and at 3 times the maximum label rate on August 18 (Table 1). Label rates were based upon the dimensions of the catch basin. Most catch basins used in this study measured 2.7 ft (82.3 cm) by 3.3 ft (100.6 cm). The square footage was 8.9 ft^2 (8,279 cm^2). Three catch basins had square footage that was twice the normal size. These large catch basins, if treated, received 2 times the amount of product added to the normal-sized catch basins. Quantities of each formulation, including the international units, date of application, and active ingredient, are shown in Table 1. Quantities used in each catch basin were measured in the laboratory before application in the field.

VectoMax was applied at a label rate (1 pouch per catch basin) (catch basins are included on the label, but the label also states that the application rate for 1 pouch is 50 ft^2, which is 5.6 times larger than the square footage of the catch basin) to 40 different catch basins (Table 1). One pouch containing 10 g of VectoMax was applied to each treated catch basin. Ten different catch basins served as untreated controls. The experiment was set up in a randomized block design with 4 treatments and 1 control per block. There were 10 replicates. VectoMax was applied on August 1 and August 22 (Table 1). Untreated catch basins were selected for each block from a table of random numbers. Sampling was done prior to treatment in all catch basins as well as at 3 to 7 days after treatment and at weekly intervals thereafter.

Larval, pupal, and egg raft sampling: Immature mosquitoes were sampled using an aquarium net with hexangular holes measuring 0.05 × 0.06 in. (0.13 × 0.16 cm) and attached to an extendable aluminum pole (Rey et al. 2006). The net measured 3.5 × 11 in. (8.9 × 27.9 cm). With the long part of the net inserted into the water, 4 sweeps along the long axis of the catch basin were used to assess numbers of mosquitoes. Contents in the net were placed in about 1 in. of clean water in a rectangular container measuring 15 × 6 × 2.5 in. (38.1 × 15.2 × 2.5 cm). Larvae were counted and recorded. In the VectoMax experiments, larvae were counted and categorized as small instars (1st and 2nd instars) or large instars (3rd and 4th instars). If present, 10 to 15 larvae were taken to the laboratory, reared to the 4th instar, and identified to species (Andreadis et al. 2005). The remaining larvae were returned to the catch basin.

Pupae were counted in the VectoMax experiments and taken to the laboratory, where they were kept in water, and adult mosquitoes were allowed to emerge. Pupae were recorded as healthy (healthy adults emerged from these specimens) or as unhealthy (pupae died or adults died without emerging successfully from the pupal exoskeleton).

Egg rafts were counted in the field and returned to the catch basin.

Rainfall: Rainfall was recorded at 1-h intervals at the Sikorsky Airport, which is located in Stratford, CT.

Statistical analysis: Differences in numbers of larvae or pupae between treated and untreated catch basins for each collection date were determined using the Kruskal–Wallis test (Conover 1980).

2009 experiments

Test materials and experimental design: VectoMax was evaluated in catch basins in Stratford, CT, in 2009. Sampling of immature mosquitoes, as described previously, was done prior to treatment in all catch basins as well as at 3 to 7 days after treatment and at weekly intervals thereafter. A single 10-g pouch containing VectoMax (500,000 *Bs* ITU) was placed into each of 40 catch basins on July 1. Twenty of these catch basins were treated again with one 10-g VectoMax pouch on August 18. Twenty catch basins were left untreated and served as controls. The experiment was set up in a randomized single block design. Three catch basins comprised each of 20 blocks. Specific treatments within each block were selected from a table of random numbers.

One catch basin was twice as large (17.8 ft^2 [16,559 cm^2]) as the others. This catch basin received 2 pouches containing VectoMax during each treatment.

Natular XRT tablets, each weighing approximately 40.5 g, contained 6.25% spinosad and had been purchased from Clark Mosquito Control, Roselle, IL. Twenty catch basins were selected, and a single tablet was placed into each of 10 catch basins on July 22, 2009. The other 10 catch basins served as untreated controls. Juvenile mosquitoes were sampled as described above.

Rainfall: Rainfall was recorded as described above.

Statistical analysis: The Kruskal–Wallis test was performed as described previously. Fisher's exact test was used to compare effectiveness of VectoMax in controlling *Culex* and *Ae. japonicus* larvae.

RESULTS

2008 experiments

Mosquito species collected in catch basins: Some 1,672 larvae were identified from untreated and treated catch basins with VectoBac CG, VectoLex CG, and VectoBac 12AS. Eight species were collected and identified. The most abundant species were *Cx. p. pipiens* (57.0%), *Cx. restuans* (29.1%), and *Ae. japonicus* (13.2%). Twenty specimens of *Ae. vexans* (Meigen) were collected. Single specimens of *Ae. cantator* (Coquillett), *Cx. territans* Walker, *Cx. salinarius* Coquillett, and *Anopheles punctipennis* (Say) were identified.

VectoBac CG, VectoLex CG, and VectoBac 12AS treatments: All 3 products significantly reduced numbers of larvae for 1 wk, but none of the treatments was significantly different from the untreated controls 2 wk after treatment following the 1st applications at the maximum label rate (VectoBac CG, 1.8 g per catch basin; VectoLex CG, 1.8 g per catch basin; and VectoBac 12 AS, 0.193 ml per catch basin) on June 30 (Figs. 1A, 1B, 1C). Similarly, following the 2nd application on July 28, VectoBac 12AS and VectoLex CG significantly reduced numbers of larvae for 1 wk. The 3rd treatment was applied at 3 times the maximum labeled rate on August 18 and resulted in a significant reduction in numbers of larvae at 3 days after treatment, and in the catch basins treated with VectoLex CG, numbers of larvae remained significantly reduced for 5 wk. VectoBac 12AS and VectoBac CG significantly reduced numbers of larvae for 4 wk and 2 wk, respectively, compared with the untreated controls.

A total of 3.86, 3.61, and 5.15 in. of rain fell during the 28-, 21-, and 28-day intervals following the 1st, 2nd, and 3rd applications (Fig. 1D). Numbers of larvae in treated and untreated catch basins declined following rainfall in excess of 2 in. of rain per 48-h period on July 23 and 24 and on September 6.

VectoMax WSP treatments: Numbers of large instars (3rd and 4th instars) were significantly lower in treated catch basins compared with untreated catch basins throughout the duration of the experiment (Fig. 2A). Large instars in treated catch basins decreased in number to less than 0.1% of the untreated controls 3 and 7 days after treatment on August 1. Numbers of large instars increased to about 12% and 40% compared with untreated controls on August 15 and August 25, 14 and 21 days after treatment, respectively. A 2nd treatment of VectoMax was added to each of the designated treatment catch basins on August 22. Large instars decreased in numbers in treated catch basins to less than 0.1% compared with numbers of large instars in untreated control basins on days 3 and 7 following treatment on August 22. Numbers of large instars increased following the 2nd treatment to about 5%, 17%, 38%, and 29% of the untreated control catch basins on days 14, 21, 28, and 35 after treatment, respectively. Numbers of small instars were similarly reduced in treated catch basins compared with the untreated ones (data not shown).

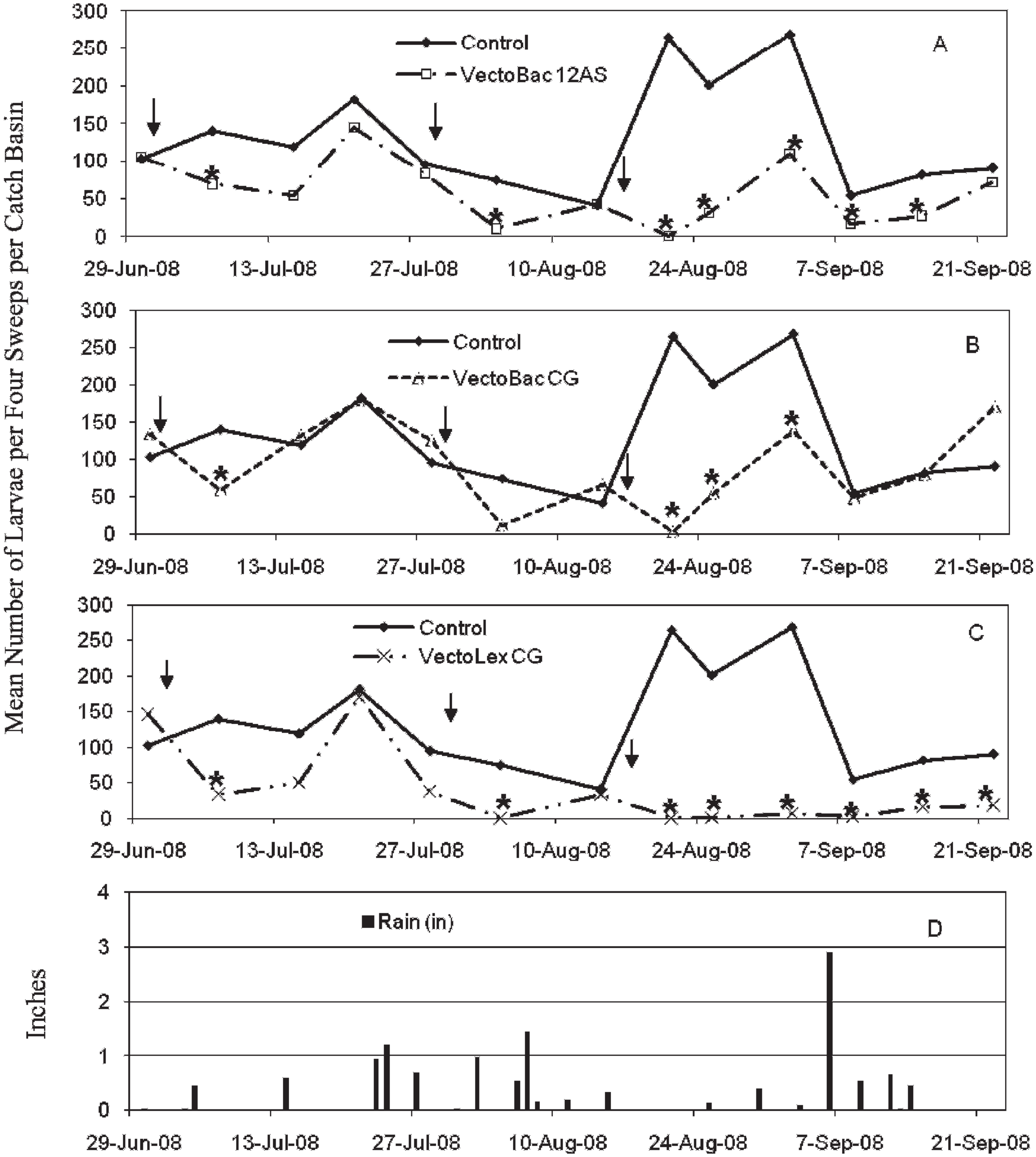

Fig. 1. Effect of 3 *Bacillus* formulations on suppression of larvae in catch basins and daily rainfall. (A) VectoBac® 12AS treatment. (B) VectoBac® CG treatment. (C) VectoLex® CG treatment. (D) Daily rainfall from June 29 through September 21, 2008, Stratford, CT. Arrows indicate when treatment was applied. *Differences between treated and untreated catch basins significant at $P < 0.05$ (Kruskal–Wallis test).

Treatment with VectoMax significantly reduced the numbers of healthy pupae after treatment on August 1 (Fig. 2B). Numbers of healthy pupae in treated catch basins remained near 0 for 14 days after treatment but increased to 33% of the untreated catch basins 21 days after treatment. Addition of VectoMax pouches on August 22 reduced numbers of healthy pupae to near 0 for the next 4 wk. Three inches of rain fell within the 1st week following treatment on August 1 and another 2.9 in. fell on September 8 (Fig. 2C). Numbers of healthy pupae and large instars were significantly reduced in the treated catch basins compared with the untreated catch basins through the middle and end of September, respectively.

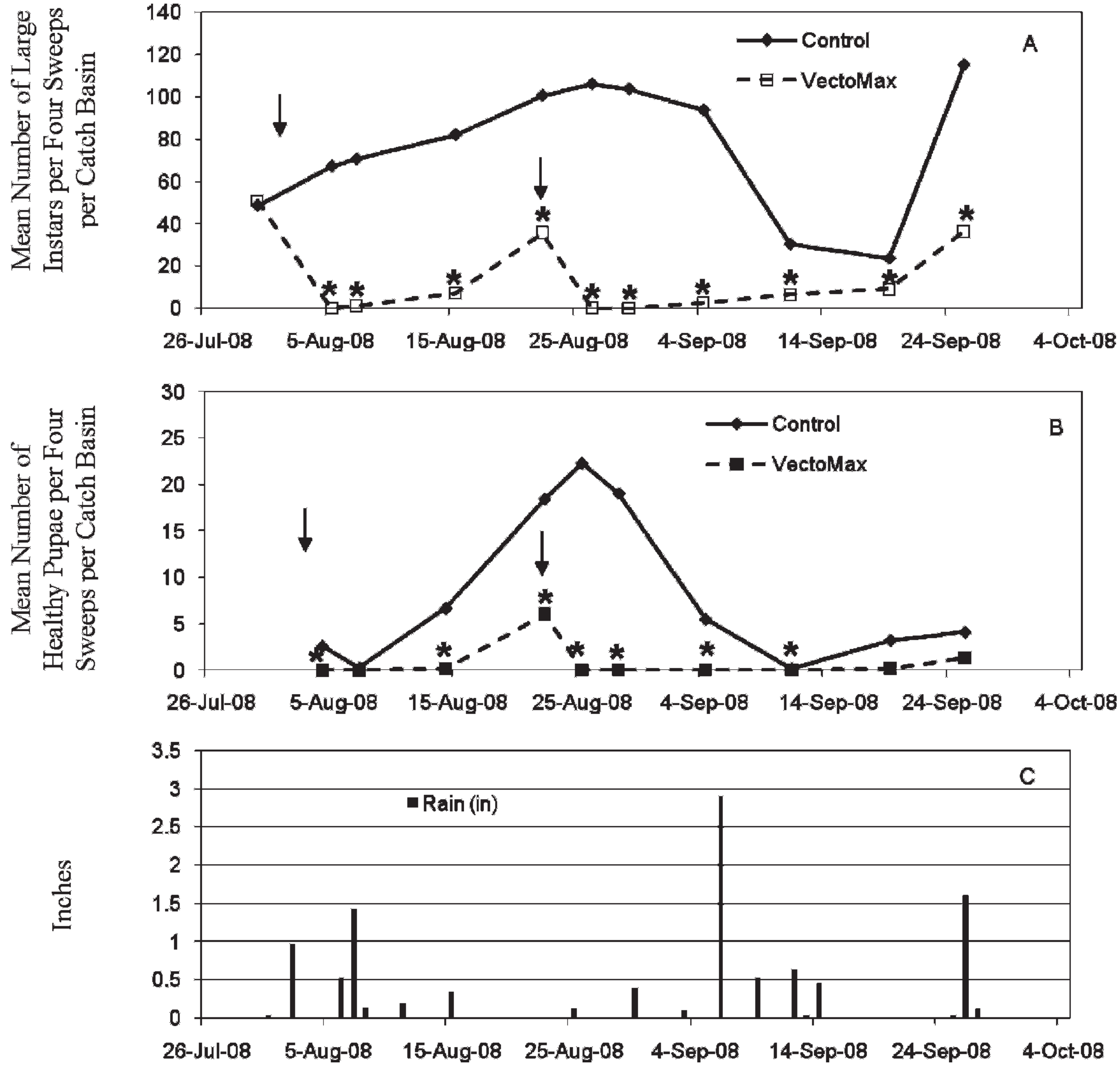

Fig. 2. Effect of VectoMax™ WSP on suppression of (A) large instars (3rd and 4th instars) and (B) healthy pupae in catch basins. Daily rainfall (C), from July 26 through October 4, 2008, Stratford, CT. Arrows indicate when treatment was applied. * Differences between treated and untreated catch basins significant at $P < 0.05$ (Kruskal–Wallis test).

Numbers of egg rafts: The average number of egg rafts collected per catch basin per day from August 4 through September 25 ranged from 1.07 to 4.85. The numbers of egg rafts in treated catch basins were not significantly different $P > 0.05$ by the Kruskal–Wallis test from those in untreated catch basins.

2009 experiments

Mosquito species collected in catch basins: Ten species were identified from 4,217 larvae collected and identified from catch basins. *Culex p. pipiens* represented 72.2% ($n = 3045$) and was the most abundant species; *Ae. japonicus* and *Cx. restuans* were also relatively abundant and made up 18.1% ($n = 763$) and 8.8% ($n = 371$), respectively. Other species collected were *Ae. vexans*, ($n = 19$), *An. punctipennis* ($n = 8$), *An. quadrimaculatus* Say ($n = 3$), and *Ae. sollicitans* (Walker) ($n = 3$). Single specimens of *Ae. canadensis* (Theobald), *Ae. cantator*, and *Cx. salinarius* were collected.

VectoMax WSP treatments: Treatment of catch basins on July 1 with VectoMax WSP resulted in an immediate and significant reduction of large instars (3rd and 4th instars) that continued for 2 wk after treatment (Fig. 3A). Thereafter, from July 22 through September 8, numbers of larvae were fewer in the catch basins treated on July 1 compared with the controls, but numbers of

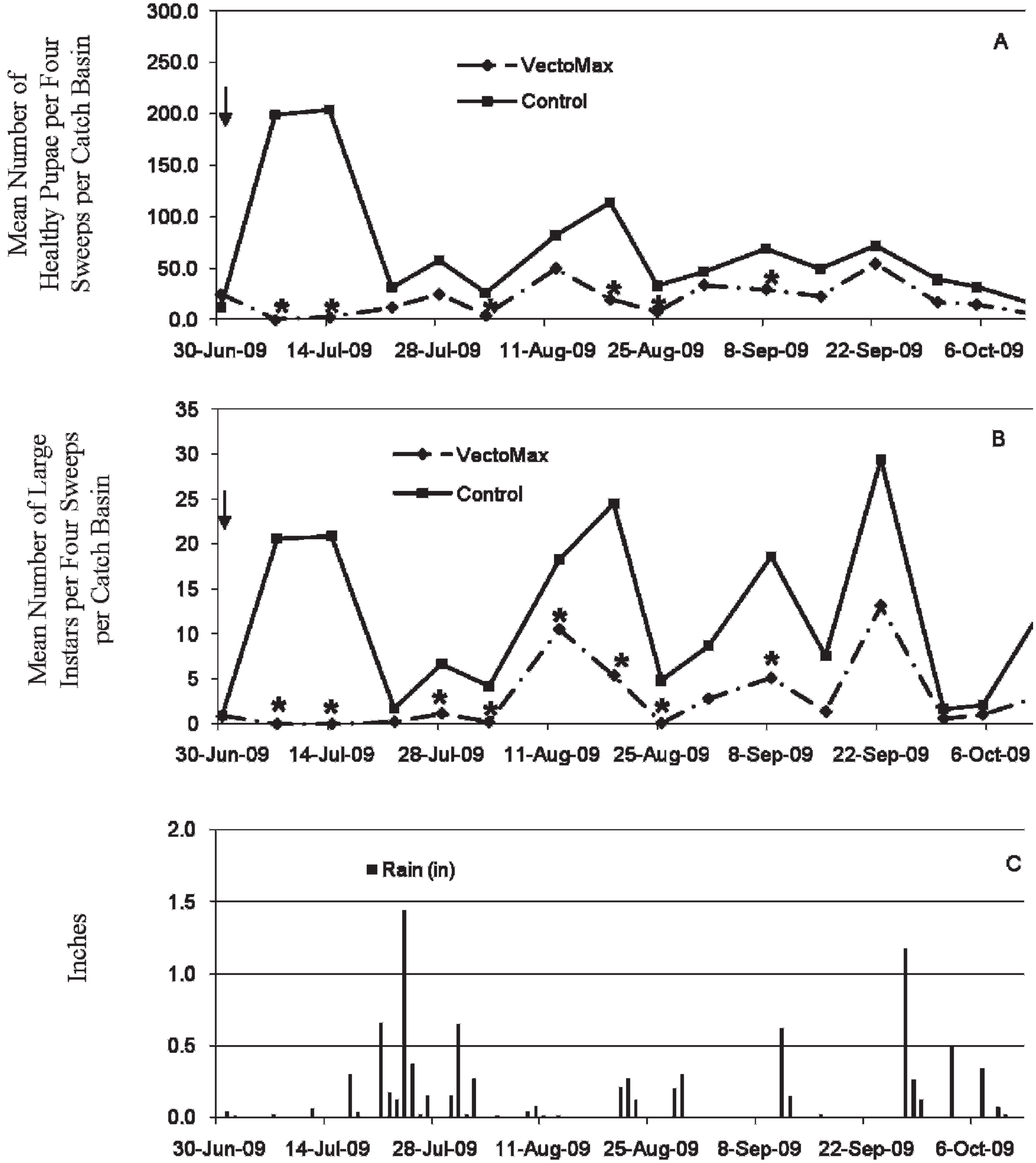

Fig. 3. Effect of VectoMax™ WSP applied once to catch basins on July 1 on (A) mean numbers of large instars (3rd and 4th instars) and on (B) mean numbers of healthy pupae. Daily rainfall (C), June 30 through October 14, 2009, Stratford, CT. Arrows indicate when treatment was applied. *Differences between treated and untreated catch basins significant at $P < 0.05$ (Kruskal–Wallis test).

larvae were not always significantly different. Among the control and catch basins treated on July 1, there were no significant differences in numbers of large instars from September 15 through October 13. Numbers of healthy pupae in catch basins treated on July 1 were lower compared with the untreated controls, often significantly so through September 8 (Fig. 3B).

In catch basins treated on July 1 and a 2nd time on August 18, numbers of large instars were significantly fewer after the 2nd treatment than in the controls through October 5 (Fig. 4A). Numbers of large instars in catch basins treated a 2nd time were often near zero. Numbers of healthy pupae in catch basins following the 2nd treatment on August 18 were near zero and were signifi-

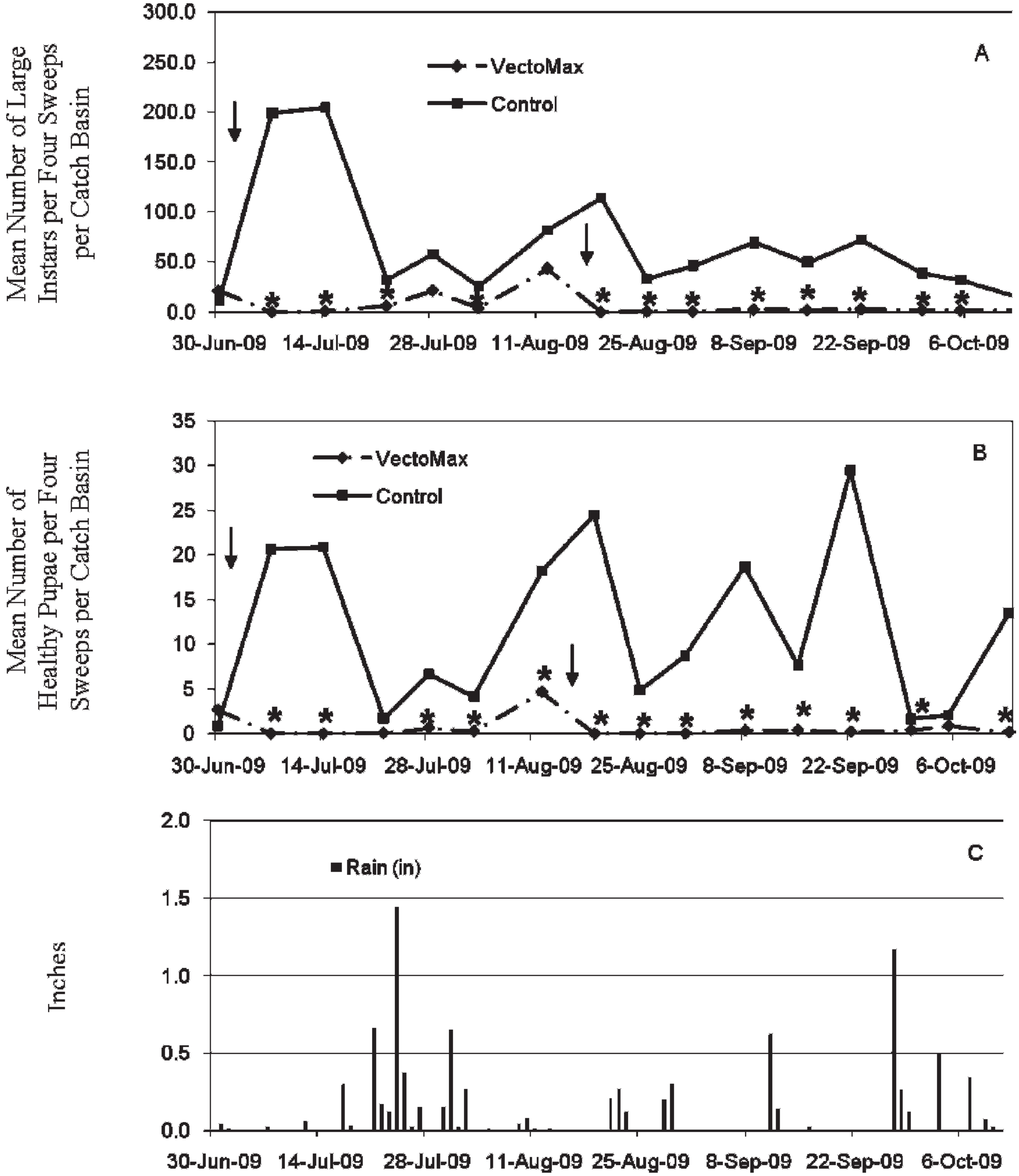

Fig. 4. Effect of VectoMax™ WSP applied to catch basins on July 1 and on August 18 on mean numbers of (A) large instars (3rd and 4th instars) and on (B) mean numbers of healthy pupae. Daily rainfall (C), June 30 through October 14, 2009, Stratford, CT. Arrows indicate when treatment was applied. *Differences between treated and untreated catch basins significant at $P < 0.05$ (Kruskal–Wallis test).

cantly fewer through the end of September than numbers of pupae in the untreated controls (Fig. 4B). Reduction of large instars and healthy pupae occurred even though 9.48 in. of rain fell from the time catch basins were treated on July 1 through October 15 (Figs. 3C and 4C).

VectoMax was effective in controlling larvae of *Ae. japonicus* and *Culex* spp. The number of healthy pupae in catch basins treated with a single application of VectoMax was significantly reduced for *Ae. japonicus* (the number of healthy pupae was 26.8% of the number from the

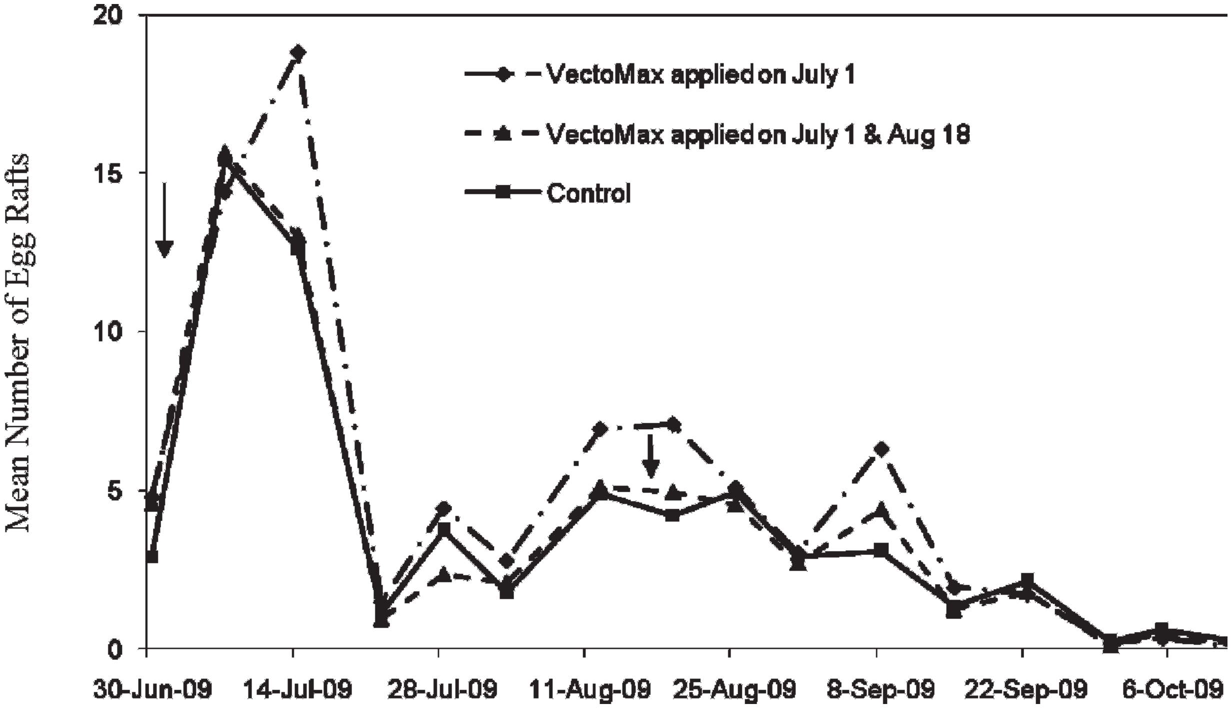

Fig. 5. Mean numbers of *Culex* egg rafts per 4 sweeps per catch basin in VectoMax-treated and untreated catch basins, June 30 through October 14, 2009, Stratford, CT. Arrows indicate when treatment was applied. There were no significant differences in numbers of *Culex* egg rafts collected among the treatment catch basins and the control catch basins at $P > 0.05$ (Kruskal–Wallis test).

untreated control) and *Culex* spp. (the number of healthy pupae was 25.7% of the number from the untreated control) ($P < 0.001$: Fisher's exact test). However, there was no significant difference in the level of control between the 2 species with a single application of VectoMax. Two applications of VectoMax were significantly more effective in controlling the *Culex* spp. (3.1%) than *Ae. japonicus* (6.0%) ($P < 0.001$; $\chi^2 = 15.84$; 2 df).

Numbers of egg rafts: There were no significant differences in weekly numbers of *Culex* egg rafts in VectoMax-treated and untreated catch basins from June 30 through the end of September 2009 (Kruskal–Wallis test; $P > 0.05$) (Fig. 5). Egg rafts were most numerous in treated and untreated catch basins on July 9 and July 16 when they averaged 15.2 and 14.8 egg rafts per 4 sweeps per catch basin, respectively (Fig. 5).

Natular XRT treatments: The application of 1 Natular XRT tablet to individual catch basins on July 22 significantly reduced total numbers of larvae for 5 wk through August 24 (Fig. 6A). Only 1 healthy pupa was collected in treated catch basins compared with 73 in the untreated ones on August 6, 15 days following treatment, but in one of the treated catch basins on August 14 and August 18, 59 and 98 healthy pupae were collected 23 and 28 days after treatment. Numbers of larvae in catch basins from August 31 through September 17 were lower in treated catch basins but were not significantly different. A total of 5.25 in. of rain fell during the experiment (Fig. 6B).

DISCUSSION

VectoBac CG, VectoLex CG, and VectoBac 12AS applied to catch basins at maximum rates consistent with the label in 2008 did not significantly reduce immature mosquitoes beyond 1 wk after treatment. A dosage 3 times the maximum label rate significantly reduced larvae and pupae for a much longer period of time. VectoLex CG significantly reduced larvae for 5 wk. The dosage levels on the labels for treatment of mosquito larvae in catch basins, where mosquito breeding is continuous, are not adequate for providing long-term control in northeastern USA without the need for frequent retreatment.

Bacillus thuringiensis israelensis and *Bs* toxins and spores in the formulation VectoMax WSP are fused together in the same particles and seem to contain the desirable attributes of each bacterial species in a single formulation. Efficacy of *Bti* has been demonstrated against several species of mosquitoes developing in a variety of different habitats, and *Bs* has been reported to be effective against *Culex* in organically enriched and other habitats and to be possibly recycled in dead larvae (Lacey 2007).

VectoMax WSP significantly reduced numbers of 3rd and 4th instars and healthy pupae in

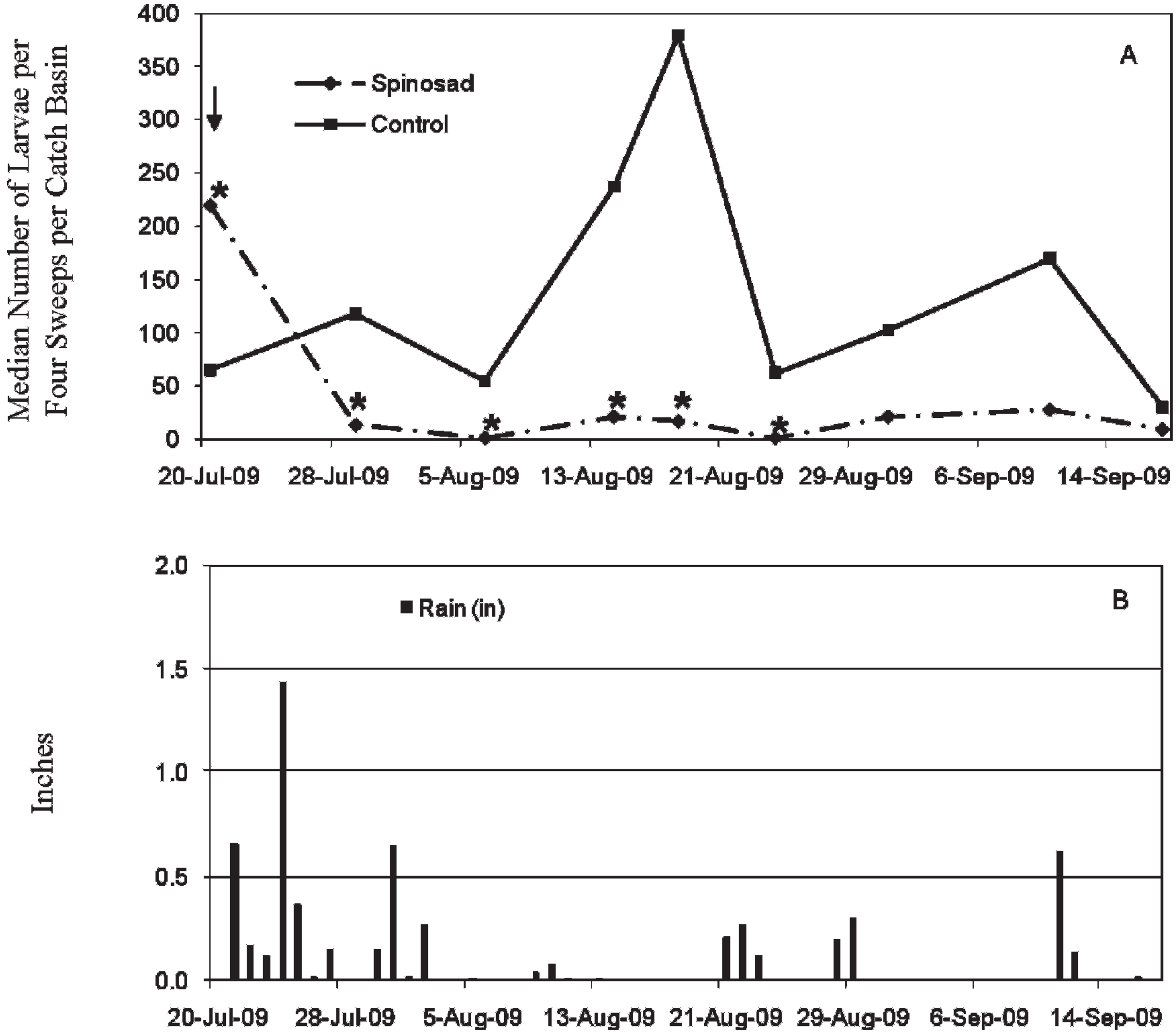

Fig. 6. Effect of Natular™ XRT (spinosad) applied to catch basins on July 22 on (A) median numbers of larvae. Daily rainfall (B), July 20 through September 18, 2009, Stratford, CT. Arrow indicates when treatment was applied. *Differences between treated and untreated catch basins significant at $P < 0.05$ (Kruskal–Wallis test).

2008, but numbers of large instars in treated catch basins at 21 days following treatment had increased to 40% of the numbers in untreated controls. A 2nd treatment was therefore applied, and numbers of large instars and healthy pupae remained significantly reduced compared with untreated catch basins for the remainder of the experiment. In 2009, numbers of large instars and healthy pupae were significantly reduced for 2 wk following treatment, but thereafter, although numbers of larvae and healthy pupae remained lower throughout the summer, differences between the treated catch basins and untreated ones were often nonsignificant. Numbers of large instars and pupae were significantly reduced following the 2nd application of VectoMax on August 18 and remained so throughout the end of September. VectoMax had been reported to be effective for several weeks in simulated catch basins (Su 2008). A 2nd application of VectoMax to catch basins is likely needed during summer to keep numbers of *Culex* and *Ae. japonicus* significantly reduced and to lower risk of human exposure to WNV. The need for relatively frequent treatments to control *Cx. pipiens* in septic tanks with formulations containing both *Bti* and *Bs* was discussed by Cetin et al. (2007).

Bacillus sphaericus has been reported to provide excellent control of *Culex* and to be moderately effective in controlling *Aedes* species and practically ineffective against species in the subgenus *Stegomyia* (Lacey 2007). A single application of VectoMax was equally effective against *Ae. japonicus*, which is in the subgenus *Finlaya*, and *Culex* spp. Two applications of VectoMax were significantly more effective in controlling *Culex* spp. than *Ae. japonicus*.

Larvae and *Bacillus* spores are flushed from catch basins by excessive rainfall (Maddock et al. 1963, Munstermann and Craig 1977, Knepper et al. 1992, Stockwell et al. 2006). The reduction of larvae following flushing is short lived, since *Culex* larvae hatch from eggs that are being laid in catch basins almost on a daily basis. Even though numbers of *Bacillus* spores may be diluted by excessive precipitation, sufficient spores from the VectoMax product apparently remained for several weeks because numbers of larvae in treated catch basins remained reduced compared with those in untreated catch basins. Residual activity may, at least in part, result from recycling of *Bs* spores (Lacey 2007).

The average rainfall in Stratford, CT, from June through September is 13.7 in. (34.7 cm). This relatively large amount of rain can affect the numbers of mosquitoes developing in catch basins and the efficacy of insecticides. The timing and amount of rainfall is a continuous challenge to those in charge of mosquito control programs. Su et al. (2003) and Rey et al. (2006) reported that rainfall affected numbers of juvenile mosquitoes in catch basins and storm drains in 3 ways: (1) flushing larvae into locations unfavorable for survival, (2) draining toxic chemicals from road areas into catch basins and drains, and (3) changing the water quality that may enhance or hinder growth of mosquitoes. Additionally, water is needed in the catch basin to ensure that mosquitoes breed continuously and reach adulthood. Also, excessive rainfall can affect the efficacy of products containing *Bti* or *Bs* through dilution by flushing the spores out of catch basins. Geery and Holub (1989) reported that rainfall of 102 mm was necessary to substantially reduce larval numbers.

Substantial numbers of *Culex* eggs were laid in catch basins in Stratford during the summer months, but there were no differences in numbers of egg rafts between treated and nontreated catch basins. The addition of *Bti* to oviposition sites of *Ae. albopictus* (Skuse) has been reported to possibly increase the number of deposited eggs (Stoops 2005). Maximum egg deposition occurred during the 1st 2 wk of July when an average of about 15 egg rafts were collected per day in each catch basin. The numbers of larvae hatching in catch basins were exceptionally high and indicative of the need for control. The cost, including insecticide and labor, of treating thousands of catch basins during summer requires that a minimum number of effective applications be made. Our data suggest that even with relatively large numbers of larvae hatching almost daily and precipitation during July through September totaling 8.2 in. (20.5 cm), 2 applications of VectoMax may be relatively effective in reducing human risk of exposure to West Nile virus by suppressing *Culex* and *Ae. japonicus* adults.

Spinosad is a natural product that has been reported to be effective in killing mosquito larvae (Bond et al. 2004, Cetin et al. 2005, Darriet and Corbel 2006, Romi et al. 2006, Perez et al. 2007, Jiang and Mulla 2009, Pridgeon et al. 2009, Sadanandane et al. 2009, Hertlein et al. 2010). Our study using a single application of Natular XRT tablet containing 6.25% spinosad showed that larvae were significantly reduced for 5 wk in catch basins that received a total of 3.96 in. (9.9 cm) of rain, although relatively high numbers of larvae and healthy pupae developed in one of the treated catch basins 3 and 4 wk after treatment. We suggest that spinosad may be useful in controlling mosquitoes in catch basins, but further study is needed to evaluate frequency of application during summer, efficacy of different formulations, and the most effective application rates.

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