

STANDARDIZED OPERATIONAL EVALUATIONS OF CATCH BASIN LARVICIDES FROM SEVEN MOSQUITO CONTROL PROGRAMS IN THE MIDWESTERN UNITED STATES DURING 2017

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ABSTRACT. During June to September 2017, 7 mosquito control programs in the midwestern United States evaluated a total of 9 catch basin larvicide formulations using similar protocols. Treated basins were monitored among study sites to observe when larvicides failed to control mosquitoes in 25% or more basins within a site. Overall, when monitoring occurred within the maximum label duration of the larvicides, sites treated with a single larvicide tablet or briquet surpassed the 25% fail threshold more often than pellet and granular larvicide formulations. In 438 of the study basins, the depth from sump bottom to catch basin lid was measured. In basins that were deeper than 5 ft (1.5 m), larvicides failed to control mosquitoes significantly more often than those 5 ft or shallower.

KEY WORDS Catch basin, effectiveness, larvicide, mosquito, sump depth

INTRODUCTION

For over a century, mosquito control programs in urban settings have routinely applied larvicides to storm-water catch basins (Chase and Nyhen 1903, Bunker 1917). Since the 1999 introduction and subsequent spread of West Nile virus (WNV) across the continental United States and the association of WNV with catch basin–produced *Culex pipiens* (L.) and *Cx. quinquefasciatus* (Say) (Anderson et al. 2006), controlling mosquitoes in catch basins has become a priority for many mosquito control programs. In support of these efforts, the Centers for Disease Control and Prevention (CDC 2013) recommends “Pesticide products and application procedures (for both larval and adult control) must periodically be evaluated to ensure an effective rate of application is being used and that the desired degree of control is obtained.” However, 2 challenges in evaluating the effectiveness of pesticides

(larvicides) used in catch basins are that there is no widely accepted standard protocol for evaluating larvicides nor is there a common “desired degree of control” among mosquito control programs. In 2017, 6 mosquito control programs in Illinois and 1 in Michigan agreed to evaluate, within the confines of their regular operations, the effectiveness of common catch basin larvicides. Collectively, these programs apply larvicides to more than 270,000 basins each season. In all, 9 different larvicides were operationally evaluated to varying degrees across the programs in 2017 (Table 1). The objective of this collaborative work was to have these operational programs utilize a standardized “pass/fail” criterion to evaluate the effectiveness of various larvicide formulations across a broad geographic area.

MATERIALS AND METHODS

Catch basin sampling techniques

Evaluations were performed from June to September 2017. Generally, each program monitored 60 to 100 treated catch basins each week. Catch basins found to be dry upon initial inspections were excluded from monitoring and subsequent analyses. More program-specific methods are given in the description of each program’s operational evaluation. Each study catch basin was sampled by removing the lid grate and taking 2 dips with a standard 350-ml dipper, except for those monitored by the Saginaw County Mosquito Abatement Commission (SCMAC) and the Macon Mosquito Abatement District (MMAD). The SCMAC sampled basins using a 4-inch (10-cm) Penn Plax[®] fish net attached to a ½-inch (1.3-cm) diam polyvinyl chloride (PVC) pipe that was 8 ft (2.4 m) long. Nets were inserted through the catch basin grate and moved in a “figure 8” motion. The net and captured contents were removed from

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Table 1. Larvicide products evaluated in catch basins across 7 mosquito control programs in the midwestern United States during the summer of 2017.

Product	Manufacturer	Active ingredient (% AI)	Applied dose per catch basin	Amount of AI in applied dose	Maximum control duration ¹	Evaluating agency
Natular™ XRT	Clarke Mosquito Control Products, Roselle, IL	Spinosad (6.25)	1 tablet	2.5 g	180 days	Northshore Mosquito Abatement District, Northfield, IL
FourStar® briquet	Central Life Sciences, Schaumburg, IL	<i>Bacillus sphaericus</i> (6.0) + <i>B. thuringiensis israelensis</i> (1.0)	1 briquet	2.62 g	180 days	Cook County Department of Public Health, Oak Forest, IL Chicago Department of Public Health, Chicago, IL
FourStar briquet	Central Life Sciences, Schaumburg, IL	<i>Bacillus sphaericus</i> (6.0) + <i>B. thuringiensis israelensis</i> (1.0)	1 briquet	1.46 g	90 days	Desplaines Valley Mosquito Abatement District, Lyons, IL
FourStar briquet	Central Life Sciences, Schaumburg, IL	<i>B. thuringiensis israelensis</i> (7.0)	1 briquet	0.95 g	45 days	Macon Mosquito Abatement District, Decatur, IL
VectoLex® FG (Granules)	Valent BioSciences Corporation, Libertyville, IL	<i>B. sphaericus</i> (7.5)	20 g of granules	1.5 g	4 wk	Desplaines Valley Mosquito Abatement District, Lyons, IL
Altosid® XR briquet	Central Life Sciences, Schaumburg, IL	Methoprene (2.1)	1 briquet	1.05 g	150 days	Northshore Mosquito Abatement District, Northfield, IL
Altosid briquet	Central Life Sciences, Schaumburg, IL	Methoprene (8.62)	1 briquet	0.60 g	30 days	Desplaines Valley Mosquito Abatement District, Lyons, IL
Altosid pellets	Central Life Sciences, Schaumburg, IL	Methoprene (4.25)	10 to 20 g of pellets	0.43 to 0.86 g	30 days	Northshore Mosquito Abatement District, Northfield, IL
			3.5 g of pellets	0.15 g		Saginaw County Mosquito Abatement Commission, Saginaw, MI
Altosid pellets WSP	Central Life Sciences, Schaumburg, IL	Methoprene (4.25)	1 water-soluble pouch (7.5 g of pellets)	0.32 g	30 days	Desplaines Valley Mosquito Abatement District, Lyons, IL
						Saginaw County Mosquito Abatement Commission, Saginaw, MI

¹ The maximum control duration is excerpted from the product label and is usually expressed as effective up to the duration shown.

the basin and the net's contents flushed into a collection container using tap water in a plastic bottle. Each basin received 1 sweep of the net weekly. The MMAD sampled basins with a standard dipper in shallow basins and a modified dipping device, the "Lander's Ladle," in deeper (>5 ft [>1.5 m]) basins. The Lander's Ladle allowed samples to be taken without removing the basin lid. Details of ladle design have been described elsewhere (MPPDAR 2016). Briefly, the ladle consists of a 1-ft-long (30-cm-long) section of 1-inch (2.5-cm) copper pipe capped at the bottom end with the open top end linked by a wire hinge to a pole. The ladle collects a 150-ml sample with each dip. The device is inserted through the basin grate and into the basin sump water. The contents of the ladle are poured into a container and inspected for larvae and pupae. Each basin was sampled with 3 dips (450 ml total) from the ladle.

Pass/fail scores for larvicide effectiveness

In the case of those basins treated with bacterial larvicides (Natular[™] XRT tablets, FourStar[®] briquets and VectoLex[®] fine granules [FG]), each basin's 2 dip or ladle samples were observed to determine if mosquito larvae and pupae were present. If so, observations of early-stage larvae (1st or 2nd instars) or late-stage larvae (3rd or 4th instars) and pupae were recorded. If late-stage larvae or pupae were present, this was considered evidence of a control failure and the basin scored as "fail" since late-stage larvae and pupae would have been exposed to the larvicides' active ingredients in the catch basin for several days and should not have survived. A similar pass/fail criterion for evaluating control effectiveness was used previously to characterize larvicide performance in catch basins (Siegel and Novak 1997, 1999; Nasci et al. 2017).

Basins treated with formulations of methoprene (all Altosid[®] products) received the same "pass/fail" score; however, the protocol for sampling was modified from that used for evaluation of bacterial larvicides. The mode of action of insect growth regulators (IGRs) like methoprene differs from that of the active ingredients of bacterial larvicides because it has a delayed control effect. Most mortality becomes evident when mosquitoes fail to emerge successfully as adults from pupae (Mulla 1995). Using a protocol similar to that described by Phillips et al. (1991), all basins received 2 dip samples, 3 Lander's Ladle samples, or a net sweep (depending on local practices) during weekly monitoring. When any 4th instars or pupae were observed in those initial samples, subsequent attempts were made to collect at least 10 4th instars and pupae. The 4th instars and/or pupae that were collected were placed in a Dart Solo UltraClear 16-oz. (0.5-liter) Clear PET (polyethylene terephthalate) Plastic Squat Cold Cup and covered with a Dart Solo Clear Flat Lid with Straw Slot Cup. These cup samples were

brought back to each program's laboratory and held at room temperature (approximately 22°C) for 2 to 7 days. More specific methods are given in the description of each control program that evaluated Altosid products. Cups were monitored daily for the presence of adults. If no adult mosquitoes successfully emerged in a cup within a specific program's desired holding time, this was considered evidence of effective control and the associated basin was scored as "pass." If 1 or more adult was observed to have successfully emerged in a cup (e.g., resting on the cup wall, flying) within the holding time, the associated basin was scored as "fail" in this same protocol.

These pass/fail criteria for both the bacterial and methoprene formulations are consistent with guidance from the World Health Organization (WHO 2005) that states, "The frequency of larvicidal treatment is determined based on the reappearance of 4th instars or pupae, in the case of common larvicides and bacterial larvicide products, or the day reduction in inhibition of emergence falls below 90% for IGRs." In the current study, a "pass" score for methoprene requires 100% emergence inhibition instead of the 90% recommended by WHO. The 90% emergence inhibition standard is a less stringent threshold for retreatment than that recommended for the direct-kill larvicides, where no adult emergence would be acceptable. This study's IGR protocol was specifically chosen to be more comparable to the "pass" score used for bacterial larvicides (which implies 100% emergence inhibition) and to be less labor-intensive than conducting estimates of emergence inhibition in an individual basin's sample of larvae and pupae.

Based on previous studies using the same or similar larvicide products in catch basins (Siegel and Novak 1997, 1999; Harbison et al. 2015, 2016; Nasci et al. 2017) it appears that 100% control effectiveness is an unrealistic expectation for many areas. Therefore, to compare effectiveness across the larvicides evaluated, a threshold of 25% or more of the basins scoring "fail" in a given site (cluster of catch basins) was set. If 25% or more basins at a given time postapplication scored "fail" within a site, this was considered widespread control failure and an indication that retreatment may be needed.

Description of mosquito control program efforts

North Shore Mosquito Abatement District (NSMAD): The NSMAD serves the suburbs directly north of the city of Chicago, IL, and covers approximately 70 mi² (181 km²). In 2017, the NSMAD applied larvicides to approximately 40,000 basins as part of their routine operations. During the summer of 2017, the NSMAD evaluated 3 different larvicide formulations; Altosid pellets, Natular XRT tablets, and VectoLex FG (Table 1).

In 2017, the NSMAD performed district-wide quality control evaluations of applied catch basin

larvicides throughout the season. The district-wide protocol is described by Nasci et al. (2017). Briefly, to evaluate basins treated with bacterial larvicides, 20 catch basins are sampled within 1-mi² (2.6-km²) treatment areas at specified durations postapplication with 2 dips of a standard 350-ml dipper. Basins were treated with either Altosid pellets at 10 to 20 g per basin, VectoLex FG at 20 g per basin, or a single Natular XRT tablet. Areas treated with Altosid pellets and VectoLex FG were retreated every 3 to 5 wk.

The protocol for evaluating Altosid-treated operational maps consisted of inspecting 12 to 32 basins for the presence of 4th instars and pupae. If 4th instars and/or pupae were present in the 2 dips, subsequent dips were taken until approximately 10 4th instars and/or pupae were collected. Samples were held for 4 days and examined daily for the presence of a successfully emerged adult.

In addition, 94 VectoLex FG-treated basins from an area known to have some of the most productive basins in the district (Nasci et al., 2017) were monitored weekly using the same pass/fail criterion. None of these 94 basins were included in the district-wide quality control inspections.

Desplaines Valley Mosquito Abatement District (DVMAD): The DVMAD serves the suburbs west of the city of Chicago, IL, and covers approximately 77 mi² (199 km²). In 2017, the DVMAD applied larvicides to approximately 42,000 basins as part of their routine operations. During the summer of 2017 the DVMAD evaluated 5 larvicide formulations; Altosid 30-day briquets, Altosid XR briquets, Altosid pellets WSP (water-soluble pouches), FourStar 45-day briquets, and FourStar 180-day briquets (Table 1). These evaluations were performed on basins that were believed to produce mosquitoes consistently and were located within 3 of the district's 31 municipalities. The DVMAD study basins were monitored weekly for pass/fail scoring from the 2nd wk of June to the 2nd wk in August.

In 1 of the 3 chosen municipalities, 78 basins were identified to evaluate the 2 different FourStar briquet formulations (45-day and 180-day). These basins were monitored weekly from the 2nd wk of June to the 2nd wk in August. Initially all 78 received a single 45-day briquet during the 1st wk of June. During the 2nd wk of July (6 wk later) these basins received a single 180-day briquet. The pass/fail scoring of the 2 formulations were analyzed separately. For each of the other 2 municipalities, 60 basins were used in the evaluations of the 3 Altosid formulations. All 120 study basins were treated with a single Altosid 30-day briquet the 1st wk and the last week of June. After this, each of one municipality's study basins were treated with a single XR briquet the 3rd wk of July and the other municipality's study basins were treated with a single pouch of Altosid pellets WSP the 1st wk of August. The protocol for evaluating all DVMAD Altosid-treated basins consisted of inspecting 20 to

60 basins for the presence of pupae. If pupae were present in 2 dips, subsequent dips were taken until approximately 10 pupae were collected and placed in a 16-oz cup. Cups were held for 2 days and examined daily for the presence of a successfully emerged adult.

City of Chicago Department of Public Health (CDPH): In 2017, CDPH coordinated the treatment of 86,000 basins within the city of Chicago (approximately 230 mi² [596 km²]) as part of routine operational efforts. During the summer of 2017, FourStar 180-day briquets were evaluated in 100 basins located within one of the city's northernmost communities. This area was specifically chosen because basins there were generally believed to be highly productive based on previous monitoring efforts. Briquets were applied to the study basins the 1st wk of June and weekly monitoring of these basins occurred from the 2nd wk of June to the 3rd wk in August (Table 1).

Northwest Mosquito Abatement District (NWMAD): The NWMAD serves the suburbs northwest of the city of Chicago, IL, and covers approximately 241 mi² (624 km²). In 2017, the NWMAD applied larvicides to approximately 48,000 basins as part of their routine operations. During 2017, all basins were treated with a single Altosid XR briquet beginning the 1st wk in June (Table 1). From the 2nd wk of June to the 2nd wk of August, 65 basins were chosen throughout the district and monitored weekly. The tendency of these basins to harbor mosquitoes was unknown as no prior data were available. The protocol for evaluating all 65 basins consisted of inspecting them for the presence of pupae with a standard dipper. If pupae were present in 2 dips, subsequent dips were taken until approximately 10 pupae were collected and placed in a 16-oz cup. Cups were held for 7 days and examined daily for the presence of a successfully emerged adult.

Cook County Department of Public Health (CCDPH): In 2017, CCDPH coordinated the treatment of 1,000 basins located in a 10-mi² (26-km²) area not covered by a mosquito abatement district or the City of Chicago's mosquito control efforts. All basins were treated with a single Natular XRT tablet (Table 1) beginning the 2nd wk of June. From the 3rd wk of June to the 3rd wk of August, 99 basins were monitored weekly in a 4-mi² (10-km²) section in the north part of the county. The tendency of these basins to harbor mosquitoes was unknown as no prior data were available.

Macon Mosquito Abatement District (MMAD): The MMAD is located within Macon County, in central Illinois, and covers approximately 101 mi² (261 km²). In 2017, the MMAD applied larvicides to approximately 6,500 basins as part of their routine operations. During the summer of 2017, FourStar 45- and 90-day briquets were evaluated in 77 basins located in the northern section of the district. This section was specifically chosen because the basins

were generally believed to be highly productive based on the monitoring results from previous years. Each of these basins received a single FourStar 45-day briquet during the 1st wk of June and a single FourStar 90-day briquet during the 1st wk of August. From the 2nd wk of June to the last week of August, the 77 basins were monitored weekly using the previously described Lander's Ladle. The pass/fail scoring of the 2 formulations were analyzed separately.

Saginaw County Mosquito Abatement Commission (SCMAC): The SCMAC serves the Saginaw County in central Michigan and covers approximately 816 mi² (2,100 km²). In 2017, the SCMAC applied larvicides to approximately 50,000 basins as part of their routine operations. During the summer of 2017 the SCMAC evaluated 2 different larvicide formulations; Altosid pellets and Altosid pellets WSP (Table 1). These evaluations were performed on basins that were believed to be highly productive within 2 adjacent townships within the county based on the results of prior monitoring efforts. The 1st larvicide applications were made the 1st wk of June, with one township's basins (20 basins total monitored) receiving an application of Altosid pellets and the 2nd township's basins receiving an Altosid pellets WSP (12 basins total monitored). The 1st township's basins were retreated with Altosid pellets during the 1st wk in July, the 2nd wk in August, and the 1st wk in September. The SCMAC study basins were monitored weekly for pass/fail scoring from the 2nd wk of June to the 2nd wk in September. The protocol for SCMAC's Altosid-treated basins consisted of inspecting each basin for the presence of pupae. If 1 or more pupae were present in sweeps of an aquatic net, subsequent sweeps were taken until approximately 10 pupae were collected and placed in a 16-oz cup. Cups were held for 7 days and examined daily for the presence of a successfully emerged adult.

Measurements of catch basin depth: In 438 basins located among NSMAD, DVMAD, CDPH, CCDPH, and MMAD study sites, the total depth of each basin (distance from lid to sump bottom) was measured by using 1 of the following 3 methods: 1) An 8-ft. (2.4-m) PVC pipe with measuring tape attached along the pipe was inserted into the basin and pushed through the sediment to the bottom of the sump. The depth from the bottom to the basin lid was noted. 2) An 8-ft. (2.4-m) PVC pipe with inches marked directly on the pipe was inserted into the basin and pushed through the sediment to the bottom of the sump. The depth from the bottom to the basin lid was then noted. 3) A 10-lb (4.5 kg) weight tied to a 25-ft (7.6-m) length of polypropylene rope was dropped into the basin with the point where the rope reached the sump lid when the weight settled marked. The weight and rope were then removed from the basin and the distance from the weight to the mark measured. The range of basin depths measured was split approximately in half and the overall percentage of fail scores observed in the shallower half of basins was

compared to that of the deeper basins using a chi-squared test for comparison of proportions.

RESULTS

From June through September 2017, 212 monitoring visits were made to the catch basin sites and resulted in a total of 6,950 inspections of over 1,600 basins across the 7 mosquito control programs.

Bacterial larvicide evaluations

During the summer, 113 total visits were made to study sites containing 19 to 100 basins treated with Natular XRT tablets, FourStar briquets, and VectoLex FG within the maximum label duration. Of these, VectoLex FG-treated sites had the lowest percentage of site visits surpassing the threshold for retreatment ($\geq 25\%$ of monitored basins within a site scoring "fail"), while FourStar 180-day briquets had the highest (Table 2). Site visits to VectoLex FG-treated basins surpassed the retreatment threshold as early as 1 wk posttreatment (1 site visit), but the majority of site visits that surpassed the retreatment threshold occurred beyond 4 wk posttreatment (15 site visits) (Fig. 1). Site visits to FourStar 45-day briquet-treated basins surpassed the retreatment threshold as early as 2 wk posttreatment for both the DVMAD and the MMAD evaluations (Fig. 2). Site visits to FourStar 180-day briquet-treated basins surpassed the retreatment threshold as early as 2 wk posttreatment for the CDPH and 4 wk posttreatment for the DVMAD evaluations (Fig. 2). Site visits to Natular XRT tablet-treated basins surpassed the retreatment threshold as early as approximately 5 wk posttreatment for the NSMAD but never surpassed the retreatment threshold during the 10 wk of CCDPH basin monitoring (Fig. 3).

Altosid larvicide evaluations

Of the 4 Altosid formulations, there were 39 total visits to study sites within the maximum label durations of these larvicides, generating 1 to 17 cup samples per visit. Of these, the pellet formulations (loose pellets and WSP) had the lowest percentage of site visits surpassing the threshold for retreatment, while the 2 briquet formulations had the highest (Table 2). Site visits to Altosid pellet-treated basins surpassed the retreatment threshold as early as approximately 1 wk posttreatment for the SCMAC and the NSMAD evaluations (Fig. 4). Site visits to Altosid pellet: WSP-treated basins surpassed the retreatment threshold as early as approximately 1 wk posttreatment for both the SCMAC and the DVMAD evaluations (Fig. 5). For the SCMAC, Altosid pellet: WSP evaluations, most site visits (6) were above the retreatment threshold for the 4 wk of monitoring, while all 3 of the DVMAD Altosid pellet: WSP site visits were above it for the 3 wk of monitoring posttreatment. There were no site visits to Altosid briquet-treated basins (30- and 150-day) below the

Table 2. Percentage of site visits surpassing $\geq 25\%$ fail threshold within the maximum control duration¹ suggested for retreatment during the summer of 2017.

Formulations	% site visits surpassing retreatment threshold (no. of total)	No. of basins sampled or no. of samples collected per site visit ²	Evaluating agency
Bacterial-based			
VectoLex® FG (granules)	10.5 (6 of 57)	19 to 94	North Shore Mosquito Abatement District
Natular™ XRT tablets	12.5 (3 of 24)	19 to 99	North Shore Mosquito Abatement District
FourStar® 90-day briquets	20.0 (1 of 5)	51 to 58	Cook County Department of Public Health
FourStar 45-day briquets	36.4 (4 of 11)	46 to 75	Macon Mosquito Abatement District
FourStar 180-day briquets	37.5 (6 of 16)	61 to 100	Macon Mosquito Abatement District
			Desplaines Valley Mosquito Abatement District
			Desplaines Valley Mosquito Abatement District
			Chicago Department of Public Health
Methoprene			
Altosid® pellets	45.5 (5 of 11)	1 to 16	North Shore Mosquito Abatement District
Altosid pellets WSP	58.3 (7 of 12)	1 to 8	Saginaw County Mosquito Abatement Commission
Altosid briquet (30-day)	100 (2 of 2)	9 and 12	Desplaines Valley Mosquito Abatement District
Altosid XR briquet	100 (13 of 13)	3 to 16	Saginaw County Mosquito Abatement Commission
			Desplaines Valley Mosquito Abatement District
			Desplaines Valley Mosquito Abatement District
			Northshore Mosquito Abatement District

¹ The maximum control duration is excerpted from the product label and is usually expressed as effective up to the duration shown.
² For bacterial-based formulations, number of basins sampled; for methoprene formulations, number of samples collected.

25% fail retreatment threshold during monitoring (Fig. 5).

Basin depth

Of the 438 basins in which lid-to-sump depth was measured, the average was 4.88 ± 0.74 ft SE, with a range of 1.83 to 8.5. There were 1,956 visits to basins 5 ft (1.5 m) or shallower of which 271 received a fail score (13.85%). These shallower basins appeared to have significantly fewer fail scores than those basins deeper than 5 ft. (449 fail scores from 2,257 basin visits, 19.9%), χ^2 (df = 1, $n = 4,213$) = 26.97, $P < 0.001$.

DISCUSSION

Although routine quality control evaluations of pesticides are recommended for all mosquito control programs that apply larvicides and adulticides, it is unknown how often these evaluations are performed. Recent studies have found some pesticide formulations commonly used for controlling mosquitoes in catch basins (i.e., tablets and briquets) may not be as effective as previously assumed (Harbison et al. 2015, 2016; Nasci et al. 2017). This led to a broader interest in determining if a similar trend was occurring in catch basin control programs elsewhere in the region. Each of the 7 mosquito control programs participating in this study had its own protocols for catch basin larvicide application and effectiveness monitoring. We attempted to standardize protocols and utilize similar measures (i.e., the pass/fail system) for evaluating effectiveness across

all programs. This allowed some comparison among the larvicide formulations.

Overall, caution is needed when attempting to compare the effectiveness of the larvicides used in this study. Prior field studies have found that the mosquito productivity of catch basins can vary widely across certain areas (Kronenwetter-Koepel et al. 2005, Stockwell et al 2006, Harbison et al. 2017). While attempts were made to identify the most consistently productive basins for evaluations, there were 2 district-wide evaluations (NWMAD and NSMAD) that likely included some less-productive basins and 1 evaluation without any prior knowledge of basins (CCDPH).

When looking at the results of the bacterial larvicide evaluations, the granular formulation (Vec-toLex FG) had the lowest percentage of fail scores when compared to the tablet and briquet formulations. However, the CCDPH site, treated with Natular XRT tablets, never surpassed the 25% fail threshold during the entire 10 wk of monitoring. In fact, this site stayed consistently below 5% fail each week. This is not consistent with results observed for Natular XRT-treated basins in an adjacent area, where some sites exceeded 25% failure by 3 wk posttreatment (Nasci et al., 2017). Many of the CCDPH basins held little or no organic material in the sump and, for 65 of these 99 basins, the sump bottom and applied Natular XRT tablet were easily visible during weekly inspections. Thus, these basins did offer an additional opportunity to observe whether Natular XRT tablets flushed out of basin sumps after periodic rains. This phenomenon was similarly observed in another study (Harbison et al.

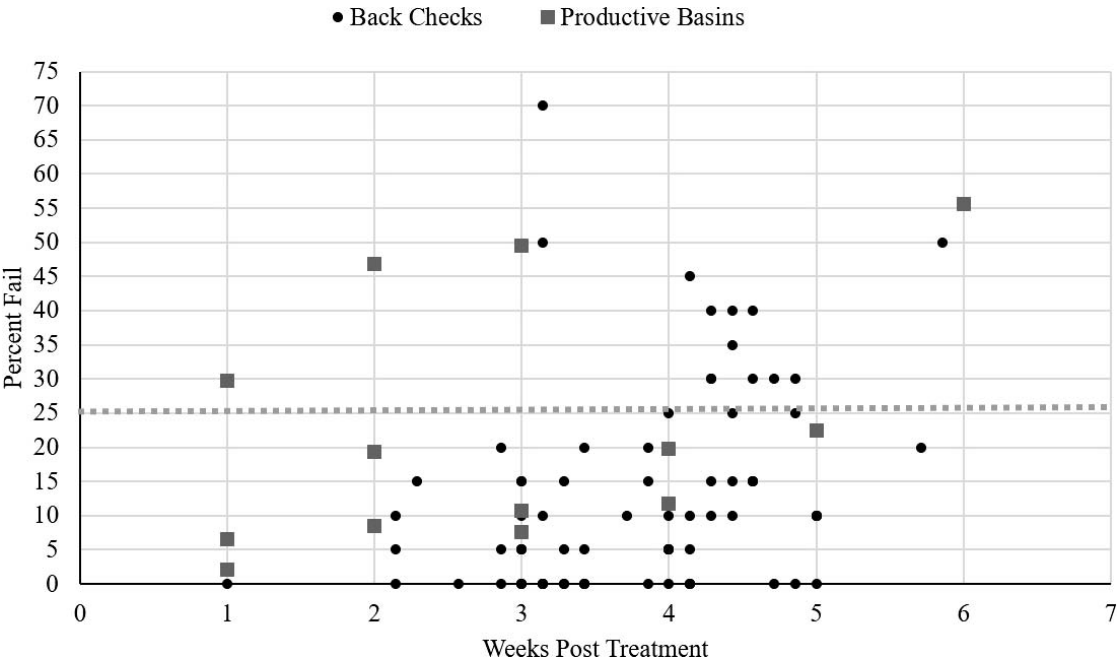


Fig. 1. Percentage of catch basins treated with VectoLex® FG (granules) that received a fail score during weekly site visits to 20 to 30 basins as part of systematic and district-wide catch basin back check efforts and during weekly visits to 94 “productive” basins known to consistently harbour mosquitoes. The dotted line represents the $\geq 25\%$ fail threshold suggested as an indication that retreatment is needed. All evaluations were performed by the North Shore Mosquito Abatement District.

2015). At 5 wk posttreatment, 37 of the 65 (56.9%) basins were missing tablets and by the end of the 10 wk monitoring period, 55 of the 65 (84.6%) were missing tablets. Upon discovery of a basin missing a

tablet, a search of the bottom was made using the dipper to ensure that it was not hidden by sediment. Despite the lack of Natular XRT tablets in many CCDPH Natular XRT-treated basins, the percentage

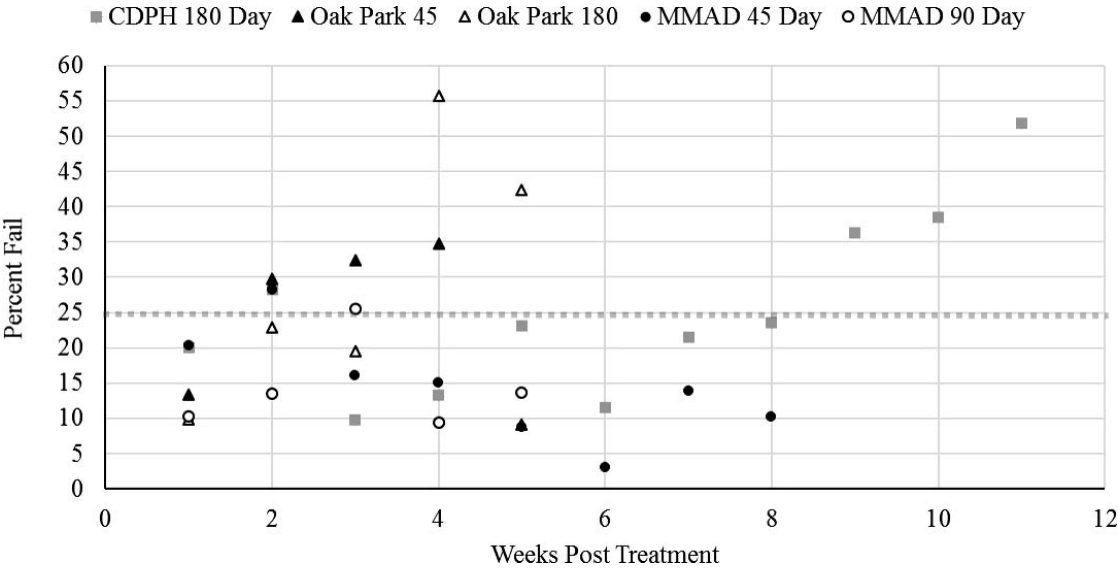


Fig. 2. Percentage of catch basins treated with FourStar® briquets (45-, 90-, and 180-day formulations) that received a fail score during weekly site visits to 77 to 100 basins. The dotted line represents the $\geq 25\%$ fail threshold suggested as an indication that retreatment is needed. The collaborating agencies were the City of Chicago (CDPH), Desplaines Valley Mosquito Abatement District (DVMAD), and Macon Mosquito Abatement District (MMAD).

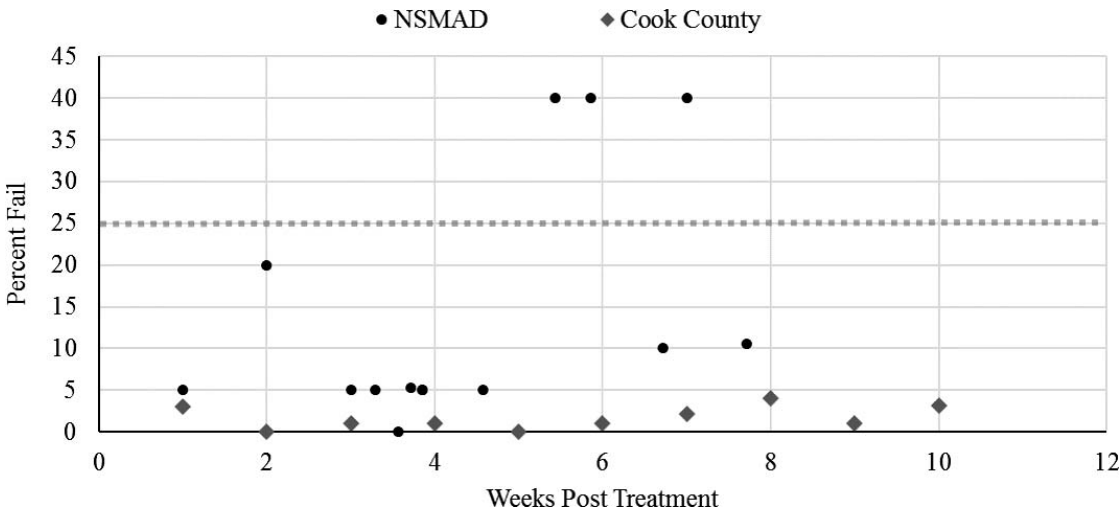


Fig. 3. Percentage of catch basins treated with a single Natular XRT tablet that received a fail score during weekly site visits to 20 to 30 basins as part of systematic and district-wide catch basin back check efforts by the North Shore Mosquito Abatement District (NSMAD) and during weekly visits to 99 basins in area not covered by a mosquito abatement district in Cook County, IL. The dotted line represents the $\geq 25\%$ fail threshold suggested as an indication that retreatment is needed.

of basins scoring a “fail” remained the lowest among all study sites of the 7 mosquito control programs. This, coupled with observations that many basins lacked organic material in sumps, would suggest that this site’s basins generally do not naturally produce mosquitoes at a high rate. Therefore, many CCDPH

basins may have scored a “pass” simply because the sump waters were not attractive to ovipositing females and thus did not harbor mosquito larvae and pupae very often. Therefore, these basins may not have been ideal for evaluations of any larvicides. When removing CCDPH basin data, the percentage

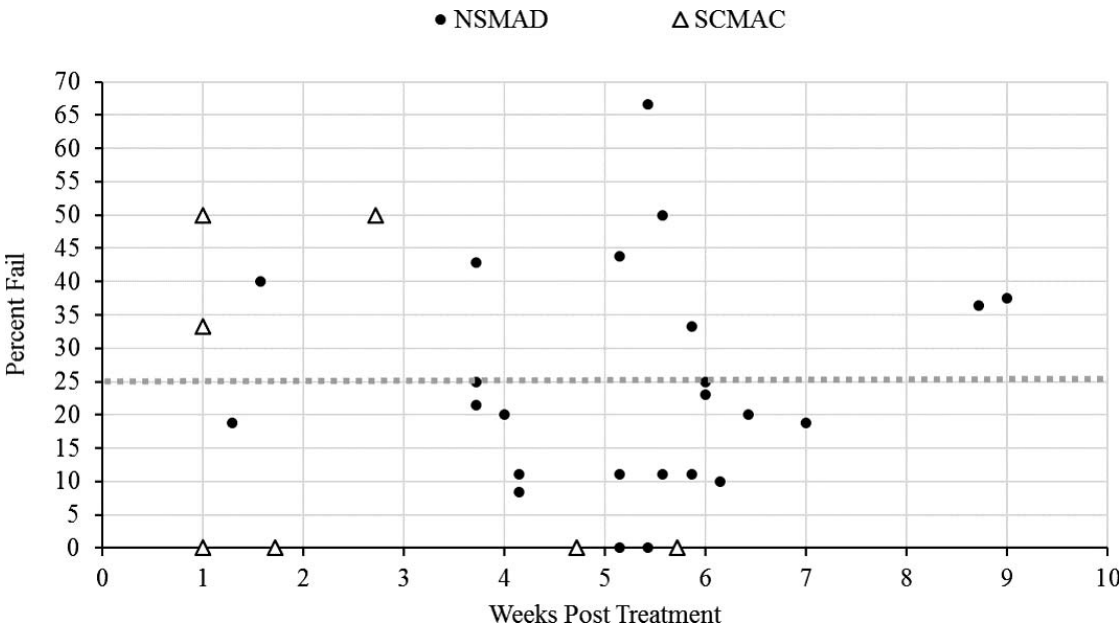


Fig. 4. Percentage of catch basins treated with Altosid® pellets that received a fail score during weekly site visits to 12 to 32 basins as part of systematic and district-wide catch basin back check efforts by the North Shore Mosquito Abatement District (NSMAD) and during weekly visits to 20 basins believed to consistently harbor mosquitoes by the Saginaw County Mosquito Abatement Commission (SCMAC). The dotted line represents the $\geq 25\%$ fail threshold suggested as an indication that retreatment is needed.

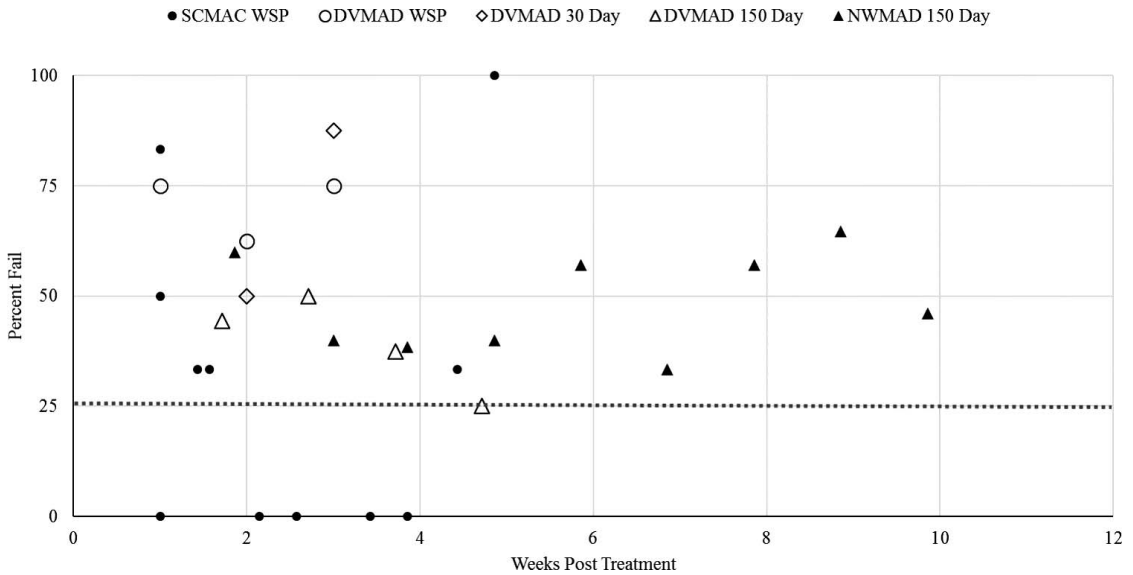


Fig. 5. Percentage of catch basins treated with Altosid[®] pellets WSP (water-soluble pouches), Altosid 30-day briquets, and Altosid 150-day briquets that received a fail score during weekly site visits to 12 to 60 basins. The dotted line represents the $\geq 25\%$ fail threshold suggested as an indication that retreatment is needed. The collaborating agencies were the Saginaw County Mosquito Abatement Commission (SCMAC), Desplaines Valley Mosquito Abatement District (DVMAD), and Northwest Mosquito Abatement District (MMAD).

of site visits surpassing the retreatment threshold for the Natular XRT-treated basins increases from 12.5% to 21.4% (3 of 14 site visits).

When comparing the effectiveness of Altosid formulations, the pellet formulations (loose pellets and WSP) had a lower proportion of fail scores in comparison to the 30-day and 150-day briquet formulations. However, the Altosid evaluations had very low sample sizes and the results should be interpreted accordingly. It became apparent early in the Altosid evaluations that it was difficult to reliably find 4th instars and pupae in basins, an observation that has been noted elsewhere (Siegel and Novak 1997, Stockwell et al. 2006). Another complicating factor for the evaluations of Altosid pellet formulations was that the applied doses varied among control programs. The SCMAC applied loose pellets at 3.5 g per basin while the NSMAD applied 10 to 20 g per basin and the water-soluble pouches (Altosid pellets WSP) are filled with approximately 7.5 g of pellets which are released when the pouches dissolve quickly upon contact with water. The label-specified application rate for the larvicide pellet and granular formulations (VectoLex FG and Altosid pellets) were given as pounds/acre and thus application doses varied based on each program's particular practices. Finally, not all Altosid evaluations utilized the same sampling protocol. The DVMAD collected only pupae in their cup samples and held them for 2 days to observe emergence while the NSMAD collected both 4th instar larvae and pupae in their cup samples and held them for 4 days to observe emergence. Thus, definitive conclusions regarding the specific

degree of control provided by Altosid larvicides in catch basins will require additional research.

Generally, the results from the comparisons of bacterial larvicides and Altosid larvicides suggest that products formulated for a single dose of a tablet or briquet per basin surpassed retreatment thresholds more often than those formulated into a dose of multiple granules and pellets. These findings agree with other field studies that have observed granular and pellet formulations to be more effective than briquet and tablet formulations (Knepper et al. 1992, Nasci et al. 2017, Harbison et al. 2018). The reasons for the apparent differences between briquets and tablets compared to granules and pellets were not investigated as part of this study. We speculate that the briquet and tablet formulations, as a point source of active ingredient, are more prone to being buried in organic sediment or completely flushed out of basins, as suggested elsewhere (Harbison et al. 2015, 2016, unpublished data; Nasci et al. 2017). The granular and pellet formulations may provide a dispersed source of active ingredient in the basin that is less prone to being completely flushed out or buried. In addition, the maximum label duration for the pellet and granule formulations did not exceed 30 days while 3 tablet and briquet formulations had a maximum label duration of 150 or 180 days. These significantly longer maximum label durations may not be a reasonable expectation for many basins.

When considering the total depth of measured basins, deeper basins were associated with a higher proportion of control failures. Again, the potential reasons for this difference were not investigated as

part of this study. One possibility is that because all basins received the same dose of a larvicide, deeper basins may hold a greater volume of sump water, thus reducing the concentration of active ingredient. Ultimately, a reduced (diluted) concentration of active ingredient would minimize the effectiveness of the larvicide in these deeper basins. Deeper basins may also capture and hold more organic material which, in turn, may make basins more attractive to ovipositing females. Another possibility could be that runoff falls farther from the street to the sump water surface in deeper basins, thereby generating more turbulence and resulting in increased flushing out and/or dissolution of larvicides. Finally, we feel that the sampling protocols and pass/fail criteria used in this study have proven valuable in evaluating larvicide effectiveness in catch basins, and are easily incorporated as a standard for operational quality control programs.

ACKNOWLEDGMENTS

The authors thank David Zazra for helpful editing and the North Shore Mosquito Abatement District trustees for their support and encouragement. The authors also thank William W. Stanuszek and Chuck Pearce of the SCMAC; Sam Force of the MMAD; Mike O'Malley of the NWMAD; Bob Holub, Paul Geery, and Mark Tomek of the DVMAD; Cort Lohff and Claudia Blanco of the CDPH; and LaTrice Porter-Thomas and Peter Gianakas of the CCDPH for their willingness to collaborate on this study. This manuscript was supported in part by Cooperative Agreement Number U01CK000505, funded by the CDC. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the CDC or the Department of Health and Human Services.

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