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Variable Efficacy of Extended-release Mosquito Larvicides Observed in Catch Basins in the Northeast Chicago Metropolitan Area

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ABSTRACT: Since the mid-1990s, the North Shore Mosquito Abatement District (NSMAD) has applied extended-release formulations of mosquito larvicides to approximately 50,000 catch basins in the suburbs north of Chicago, IL, USA. This is performed as part of NSMAD's efforts to reduce local populations of the West Nile virus vector, *Culex pipiens*. Analyses from NSMAD's monitoring of larvicide-treated basins throughout the District over the 2014 and 2015 seasons suggest that larvicides intended to provide extended durations of control (30–180 days) failed to provide control for the maximum duration specified on the product label in approximately 25% of the District's basins. For larvicides designed to last up to 180 days (or about 26 weeks), failures were found at 1–15 weeks after treatment with most found at five weeks posttreatment. For larvicides formulated to last up to 30 days, failures were found at one to four weeks after applications with most found at three weeks posttreatment. The highest percentages of failing basins (ie, containing late-stage mosquito larvae or pupae during the specified product effectiveness period) were found in communities on the eastern side of the District, bordering Lake Michigan. As the larvicides appeared to function properly in the majority of monitored basins, it appears that the failures likely resulted from basin-specific physical factors (ie, basin volume, sediment content, and hydrology) that cause either product removal or a reduction in the concentration of the larvicide's active ingredient below the effective levels in these basins.

KEYWORDS: larvicide, catch basin, mosquitoes, West Nile virus

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Introduction

Stormwater catch basins are common sources of permanent or semipermanent standing water in urban and suburban residential areas and are considered to be important habitats for *Culex pipiens*, a primary mosquito vector of West Nile virus (WNV).[1–5] Because tens of thousands of these structures can exist within a mosquito control program's operational area, it is common practice to treat all or most of these basins with at least a single application of extended-release larvicides in the form of tablets or briquets (Altosid® XR, FourStar®, and Natular™ XRT) designed to provide larval control from 30 to as long as 180 days (about 26 weeks). These products have grown in popularity as the prospect of a single application that can potentially last an entire season is appealing logistically and financially to many mosquito control and WNV management programs. For more than a decade, the North Shore Mosquito Abatement District (NSMAD) has applied extended-release larvicides seasonally to approximately 50,000 catch basins in the 13 communities within the District's 207 km^2 (80 square miles) operational area located just north of Chicago, IL, USA. This is performed as part of the NSMAD's efforts to reduce local populations of the local WNV vector species, *C. pipiens*. However, there is growing evidence that extended-release larvicides are not effective for as long as expected.[2,4–9] Here, we report the findings observed from two years of routine catch basin monitoring performed by the NSMAD staff. Although not a part of a formal study, we hope to utilize monitoring data to (1) identify the proportion of extended-release larvicide treatments that did not provide the advertised maximum duration of control in catch basins and (2) determine if there was a spatial pattern in the decrease in treatment efficacy.

Methods

To guide the catch basin larvicide program, the NSMAD divides its operational area into 76 approximately one-square mile (2.6 km^2) treatment maps (Fig. 1). Monitoring effectiveness of the larvicide treatments was conducted as described previously.[8] Each week during the period from June to September of 2014 and 2015, at least five catch basins were

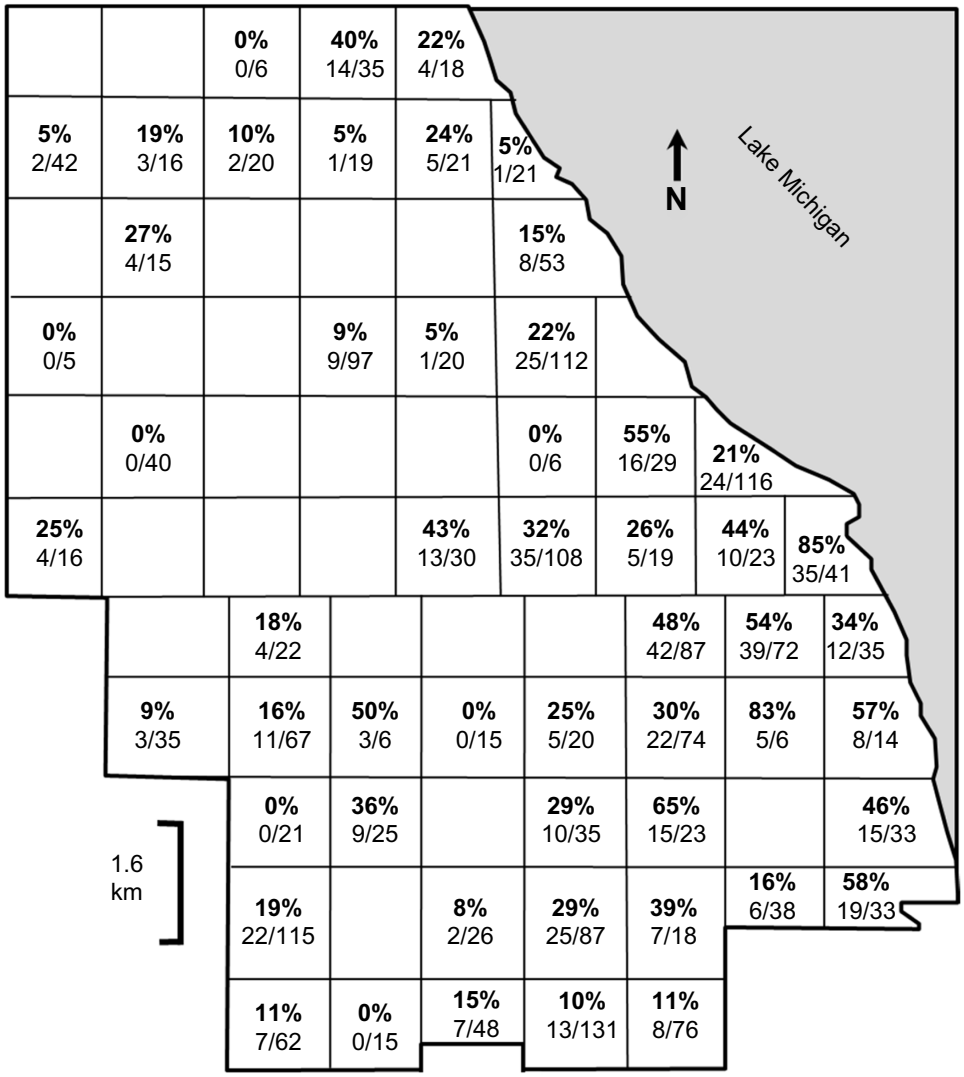

Figure 1. Percentage of catch basins in which extended-release larvicides were observed to fail within 53 approximately 2.6 km^2 (one square mile) operational maps of the NSMAD from 2014 to 2015. Those maps without data had either no basins monitored during these years or only basins monitored prior to larvicide applications.

inspected by a single NSMAD technician for the presence of mosquito larvae and pupae from each of 12–23 treatment maps. Monitoring was performed by removing the circular grate of each structure with a manhole hook and taking two dip samples using a standard 350 mL dipper. The total number of immature stages of mosquitoes collected in each dip was recorded for each dip as well as the number of late immature stages (fourth instar larvae and pupae). In those cases where catch basin sump water was clear enough to see the entire bottom of the structure, the presence of larvicide tablets was noted. When possible, a search of the bottom was made using the dipper to determine if larvicide tablets were present but hidden by sediment and debris in the sump.

Treatment protocols for the 2014 season consisted of applying Natular™ XRT 180-day extended-release tablets (XRT, 6.25% spinosad; Clarke Mosquito Control Products, Inc.) and Natular™ T30 30-day tablets (T30, 8.33% spinosad; Clarke Mosquito Control Products, Inc.) and have been published previously.[8] For the 2015 season, initial larvicide applications began in the first week of June and ended in the second week of August. Basins in 54 treatment maps received a single XRT, basins in 21 maps received a single T30, and basins in one map received a single FourStar® 180-day briquet (6% *Bacillus thuringiensis israelensis* and 1% *Bacillus sphaericus*; Central Life Sciences). The second round of larvicide treatments began from mid-August 2015 once the first round of larvicide applications had completed and extended to mid-September with basins in 9 XRT-treated maps and 12 T30-treated maps receiving an additional T30 tablet and basins in 5 XRT-treated maps receiving a combined application of BVA 2™ Mosquito Oil (97% mineral oil; ADAPCO, Inc.) and VectoLex® FG granules (7.5% *B. sphaericus*; Valent BioSciences Biotechnology Company). All larvicides were applied at label rate and as per the labeled directions. A summary of larvicides used is provided in Table 1. Data from 2014 and 2015 were combined for the subsequent analyses. A larvicide application

was deemed to have failed when one or more late immature stages (fourth instar larvae and pupae) were observed in the two dip samples. This indicates that the larvicide's active ingredient failed to kill these mosquitoes despite being exposed for at least a week during their earlier larval stages. The NSMAD set ≤5% as an acceptable failure level (number of treated basins holding ≥1 fourth instar larva or pupa divided by the total number of treated basins monitored) for monitored basins in a treatment map. Those treatment maps observed to hold a higher percentage would indicate that an alternative to extended-release larvicides should be considered for that area. Precipitation data were downloaded from a nearby weather station of the National Oceanic and Atmospheric Administration's National Weather Service Forecast Office located at the Chicago O'Hare Airport (http://www.nws.noaa.gov/climate/index.php?wfo=lot). These data were used to compare the amount of rainfall in the 2014 and 2015 seasons with the rainfall in the earlier years.

Results

During 2015 (1,103) and 2014 (1,064), a total of 2,167 catch basins were monitored after treatment with extended duration larvicide products. Of these treated basins, extended-release larvicide applications failed before the expected duration of control had passed in 540 catch basins (24.9%). From 2014 to 2015, a total of 316 (65.9%) of the 479 basins with visible sump bottoms were observed to be missing the tablets. Of those missing the tablets, 37 basins (13.2%) had at least one or more fourth instar larva or pupa in the two dip samples. Of the 163 basins observed to contain a larvicide treatment during an inspection, only three basins (1.8%) were found to have at least one or more fourth instar larva or pupa in two dip samples. Since 2014 and 2015, the treated basins were monitored from 53 of the 76 treatment maps, and of these, only 11 maps (20%) were found with a percentage of failing basins of ≤5% (Fig. 1). The rest of the maps had failure rates ranging from 8% to 85%. The highest failure rates were observed in the maps located in the southeast part of the NSMAD's operational area (Fig. 1).

In the second half of the 2015 season, following the determination that Natular™ XRT and T30 tablets were not providing the expected duration of control, alternative control procedures were evaluated. Five XRT-treated maps located in the southeast part of the District received an additional combined application of BVA 2™ Mosquito Oil and VectoLex® FG granules. Also basins in one treatment map received a single FourStar® 180-day briquette instead of XRT or T30 tablets. According to the VectoLex® FG label, four weeks (approximately 30 days) is the maximum expected duration of effectiveness. Eighteen of the BVA 2™- and VectoLex® FG-treated basins were sampled within four weeks of the application of these larvicides, and of these, seven basins (38.9%) held late immature mosquito stages. BVA 2™, as other mosquito larvicide oils, provides immediate but short-term control and tends to break down quickly when the water surface is disturbed (eg, from an influx of rain and runoff). BVA 2™ was applied to kill existing late immature stages immediately, while VectoLex® would provide a sustained control of newly hatched mosquito larvae. Twenty-eight FourStar®-treated basins were sampled within seven weeks of the initial applications, and of these, 14 basins (50.0%) held late immature mosquito stages. For basins treated with 180-day larvicides, failures were found at 1–15 weeks after applications with a mode of five weeks (65 of the 472 basins). For basins treated with 30-day larvicides, failures were found at one to four weeks after treatment with a mode of three weeks (27 of the 68 basins). The precipitation for the months of June to September in both 2014 and 2015 was similar to that of the previous four years (Table 2).

Discussion

Over the two years of catch basin monitoring, failure of extended-release (180 and 30 days) larvicides was observed in approximately 25% of treated catch basins distributed throughout the NSMAD's operational area. Preliminary observations on the use of VectoLex® FG granules and FourStar® briquets as alternatives to Natular™ XRT and T30 tablets did not provide an improved duration of control, with 38.9% of VectoLex-treated basins failing within four weeks of treatment and 50% of FourStar-treated basins failing within 180 days of treatment. These observations require further investigation as fewer basins were treated with these larvicides and sampled when compared to those treated with Natular™.

There did appear to be geographic heterogeneity in the performance of the extended duration larvicides across the District. In these current analyses, larvicides applied to basins located in the southeast quarter of the District failed before the expected control duration had passed at a higher

Table 1. Larvicides labeled for use in catch basins that were applied by the NSMAD during the 2014 and 2015 seasons.

LARVICIDE	ACTIVE INGREDIENT	FORM	LABELLED MAXIMUM DURATION
Natular™ XRT	6.25% spinosad	Tablet	up to 180 days
Natular™ T30	8.33% spinosad	Tablet	up to 30 days under typical environmental conditions.
FourStar®	6% *B. thuringiensis israelensis* and 1% *B. sphaericus*	Briquet	up to 180 days or more
VectoLex® FG	7.5% *B. sphaericus*	Granules	Should be reapplied as needed after 1 to 4 weeks
BVA2™	97% mineral oil	Oil	None given

Table 2. Total rainfall in centimeters from June to September 2010 to 2015.

YEAR	TOTAL RAINFALL (cm)
2010	49.8
2011	48.5
2012	21.3
2013	32.8
2014	50.7
2015	42.6

Note: The 30-year average for this time period is 38.8 cm.

percentage than other areas. The reason for this geographic variance remains unknown. However, it is clear that some treatment maps had relatively low percentages or no failing basins. Indeed, long-term control was achieved in 75.1% of all sampled treated basins. In basins where the treatment product was visually confirmed to be present, only 1.8% of the basins were found to have failed when compared to 13.2% of basins with missing treatments.

That larvicides appear to work in some basins and not in others suggests that the causes of failure are more associated with basin-specific physical factors, such as sump volume and the amount and type of debris captured in basins, rather than the effectiveness of the active ingredient. It is possible that the larvicide products may have been lost prematurely either through flushing out of basins or via rapid degradation from high inflows of rain and/or runoff.[8] Similarly, the dispersal of active ingredients may be hindered when tablets and briquets became completely buried in sump debris.[8] Collectively, these phenomena may play a significant role in the treatment failures we observed. Whether such factors are permanently associated with specific basins or whether this is a condition that varies over time as other related factors change (eg, weather, water use, and catch basin maintenance frequency) is yet to be determined with additional research. It is important for all catch basin larviciding programs to routinely monitor basins and identify areas prone to failure as well as identify other larvicide alternatives.

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Author Contributions

Conceived and designed experiments: JEH, MH, RSN. Performed the experiments: JEH, MH, AR. Analyzed the data: JEH, RSN. Wrote the first draft of the article: JEH, PCC, CX, MH, AR, RSN. All authors reviewed and approved the final article.

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