Reduced productivity of *Culex pipiens* and *Cx. restuans* (Diptera: Culicidae) mosquitoes in parking area catch basins in the northeast Chicago metropolitan area

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ABSTRACT: From June to September, 2016, 100 catch basins in eight parking areas were monitored weekly for the presence of mosquito pupae in the operational area of the North Shore Mosquito Abatement District (NSMAD) located just north of Chicago, IL, U.S.A. Weekly results from these basins were compared to weekly samples taken from residential street catch basins, the most common type of catch basin treated seasonally by the NSMAD with larvicides. Over the 17 study weeks, residential street basins had a mean rate of productivity (pupae per basin-visit) 12 times that of parking area catch basins. The two parking area sites with the highest mean rate of productivity were associated with county forest preserves. Productivity in both street and parking area basins was positively associated with the presence of three or more deciduous trees within 20 m of basins and if they were located directly adjacent to curbs. Alternatively, productivity was negatively associated with the proportion of impervious surface within 10 m of basins and weekly rainfall. Findings suggest that reduced catch basin larvicide applications may be appropriate in many parking area sites. ***Journal of Vector Ecology*** **42 (1): 148-154. 2017.**

Keyword Index: Catch basin, mosquito, trees, parking areas.

INTRODUCTION

Catch basins collect and conduct surface runoff in a way that reduces the likelihood of flooding and are essential elements of storm water management systems. Their design often includes a sump or vault below the outflow pipe that collects sediments and other debris, preventing this material from entering and clogging the outflow pipes. These sumps are often deep enough to permanently hold water and as a result, provide a habitat for aquatic stages of mosquito vector species, including *Culex pipiens* L., *Culex quinquefasciatus* Say, and *Culex restuans* Theobald (Covell and Resh 1971, Munstermann and Craig 1977, Stockwell et al. 2006, Anderson et al. 2011, Rydzanicz et al. 2016), *Cx. quinquefasciatus* (Say) (Maddock et al. 1963, Rey et al. 2006, Molaei et al. 2007), *Aedes albopictus* (Skuse) (Prioteasa et al. 2015, Vallorani et al. 2015) and *Ae. aegypti* L. (González and Suárez 1995, Suárez-Rubio and Suárez 2004, Manrique-Saide et al. 2013). Because tens of thousands of these structures can exist in an urban-residential area, catch basins are often the most commonly treated standing water in a mosquito abatement district and the resources needed to apply larvicides to catch basins can be significant. For example, the 70 sq. miles served by the North Shore Mosquito Abatement District (NSMAD), located just north of Chicago, IL, U.S.A, includes approximately 40,000 residential street curbside catch basins and several thousand additional catch basins in off-road locations such as parking areas and residential properties. The NSMAD estimates that in 2016 the cost of labor alone for a single round of larvicide applications to these basins ranged from US$20,000 to $25,000. Depending on the larvicide used, the total cost to the NSMAD for a single round of catch basin treatments can be over US$200,000.

However, there is some evidence that at certain sites, the importance of catch basins as mosquito producers may be diminished. Kronenwetter-Koepel et al. (2005) found that seven untreated catch basins sampled weekly in "high-intensity" urban areas (with >50% impervious land cover) held about 15% of the mosquitoes found in seven untreated basins in "low-intensity" urban areas (21 to <50% impervious land cover). The following year and in the same study area, Stockwell et al. (2006) observed that 50 catch basins sampled weekly in similarly-named "high-intensity" urban areas (<20% of land area covered in vegetation) held a little more than a third of the mosquitoes found in 50 basins in "low-intensity" urban areas (areas mixed with impervious surfaces and vegetation). Those authors suggested that a factor in these observed differences may have been the volume of organic debris captured in basin sumps. Basins in the "high-intensity" urban areas with more impervious surfaces (asphalt, pavement, etc.) likely contained less organic matter in sumps than those in "low-intensity" areas that had more trees and other vegetation nearby. This leads to the assumption that basins containing larger amounts of organic detritus provide more larval food, are more attractive to ovipositing female mosquitoes, and may ultimately be more productive than catch basins that accumulate less organic debris (Carpenter 1983, Merritt et al. 1992, Walker and Merritt 1988, Harbison et al. 2009, Gardner et al. 2013). Increased density of vegetation may also provide more mosquito harborage, increasing the abundance of mosquitoes very near these sites. Thus, if some basins are truly less productive and can be identified, operational costs could be reduced if these basins fail to contribute significantly to the adult mosquito populations and could remain untreated or be treated less frequently (Rey et al. 2006, Stockwell et al. 2006). It is not operationally feasible to measure the amount of organic material contained in sump debris for even a small number of catch basins and is likely beyond the means of most mosquito control programs. Additionally, data on sump debris may not be as informative for mosquito productivity as directly sampling the number of mosquito larvae and pupae in basins over time.

A more achievable approach is to identify sites that would be expected to have basins that accumulate less organic material in the sumps and thus would produce fewer mosquitoes. Parking areas are ideal sites for such a study. They are ubiquitous, easy to identify and, because of their expansive impervious surfaces, would likely have basins with less organic sump material accumulation and thus less mosquito production. Our objectives for this study were to: 1) estimate mosquito productivity in catch basins found in a variety of parking area sites, 2) compare productivity of these parking area basins to that of residential street basins, and 3) characterize factors that may be associated with mosquito productivity in catch basins that may be used to identify reduced-productivity habitats.

MATERIALS AND METHODS

Site descriptions

Eight parking area sites within the 181 km^2 operational area of the NSMAD were selected for use in this study. For the purpose of this study, we define "parking areas" to be paved areas of properties that hold multiple spaces specifically intended for parked cars. The sites represented parking areas in different types of properties and varied in the extent of impermeable surface and proximity of deciduous trees (Table 1). Within each of the parking area sites, ten or 20 basins were chosen for repeated sampling. In all sites, except for Site 8, the cemetery, basins were located adjacent or near designated parking spots. In Site 8, basins were located along cemetery roadways used for both vehicular travel and parking. For comparison, a ninth study site was included and consisted of 50 curbside catch basins in four residential communities in the district (Figure 1). These basins were distributed among several communities and are typical of many of the catch basins regularly treated by NSMAD. These basins also served as untreated controls in a companion study of larvicide effectiveness that will be reported separately. None of the catch basins in this current project received larvicides, and all 150 remained untreated throughout the 2016 mosquito season.

Study design

Catch basins included in this study were monitored weekly for 17 weeks from June to September, 2016 for the presence of mosquito pupae by removing the circular grate of each structure with a manhole hook and taking two dip samples using an extendable 350 ml dipper. The total number of pupae observed from the two dips was recorded. The number of pupae was recorded rather than larval stage and abundance. We believe that counts of pupae are more representative of the number of adults successfully emerging from basins than larval stages and provide a better representation of the productivity of the habitat. Counts of pupae have been used to estimate mosquito productivity in a previous study (Barrera et al. 2006). Additionally, pupae are easier to identify and count in the field than larval stages and distinguishing between instars can be difficult. An adult emergence trap has been developed for use in catch basins by Hamer et al. (2011) that more directly measures adult mosquito productivity.

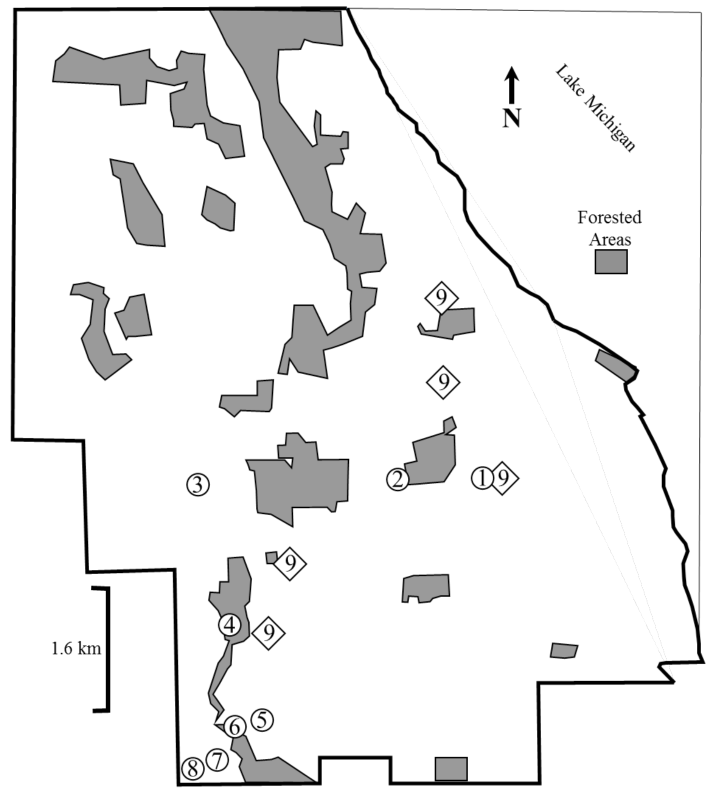

Figure 1. Map of the North Shore Mosquito Abatement District operational area highlighting the approximate locations of forested areas, the eight parking area study sites (circles 1-8) and the five residential study sites (diamonds marked with 9).

However, due to the expense of these traps, the relatively large number of basins in this study, and the depth of study basins (over 3 m deep in some cases), dip samples were considered sufficient and significantly more feasible logistically. During ten of the 17 weeks, single dip samples of pupae were taken from one to three study basins across all parking lot sites, placed into 21 x 12 cm rearing containers ("Mosquito Breeders": Bioquip® Products), and allowed to emerge. The number, sex, and species of emerged adults were recorded.

To investigate factors that may be associated with the presence of mosquito pupae in catch basins in these habitat types, we measured two structural basin characteristics of total depth of the basin (lid to sump bottom) and estimated volume of sediment held by basin sumps. We also measured three characteristics of the habitat immediately surrounding the basins, including the proportion of area within a 10 m radius surrounding a basin that was impervious surface (e.g., asphalt, cement, roofs), the presence of three or more deciduous trees within a 20 m radius of a basin, and whether basins were located directly adjacent to curbs or "curbside." The two distances utilized for the first two site characteristics were based on previous experience and observation of sites. These five site and basin characteristics were chosen for analyses because they could be associated with increased sump organic material and thus increased catch basin mosquito productivity. The total depth of each basin (distance from lid to sump bottom) was measured by inserting a 3 m long pole with measuring tape attached into the basin and pushing it through

Table 1. Measured basin and site characteristics of 100 parking area and 50 residential street catch basins (mean ± SE) monitored weekly for mosquitoes in Northeast Chicago Metropolitan Area, during June to September, 2016.

	Parking Areas									
	Site 1 N=10	Site 2 N=10	Site 3 N=10	Site 4 N=10	Site 5 N=10	Site 6 N=20	Site 7 N=10	Site 8 N=20	Site 9 N=50	Total for sites 1-8: Parking Areas N=100
Use	Multi-family residential	Shopping Mall	Grocery Store + Multi-family residential	Forest Preserve	Commercial	Church	Forest Preserve	Cemetery	Residential Street	
Basin sediment volume (m^3)	0.01 ± 0.01	0.39 ± 0.09	0.27 ± 0.07	0.09 ± 0.02	0.16 ± 0.05	0.15 ± 0.05	0.39 ± 0.03	0.08 ± 0.02	0.22 ± 0.03	0.15 ± 0.02
Total depth, lid to bottom (m)	1.73 ± 0.17	2.00 ± 0.17	2.75 ± 0.16	1.41 ± 0.9	1.92 ± 0.21	1.5 ± 0.08	1.8 ± 0.12	1.47 ± 0.08	0.73 ± 0.06	1.76 ± 0.06
Proportion impervious surface within 10m	0.77 ± 0.05	0.94 ± 0.02	0.90 ± 0.02	0.45 ± 0.02	0.95 ± 0.02	0.86 ± 0.04	0.52 ± 0.02	0.62 ± 0.02	0.69 ± 0.02	0.75 ± 0.02
Total basins that have ≥3 deciduous trees within 20m	10/10	6/10	5/10	10/10	2/10	14/20	3/10	19/20	50/50	69/100
# of curbside basins	4/10	2/10	0/10	10/10	0/10	2/20	10/10	17/20	50/50	45/100

Table 2. Effect of univariable basin and site characteristics on the expected count of pupae found in 100 parking area and 50 residential street catch basins monitored weekly for mosquitoes in Northeast Chicago Metropolitan Area, during June to September, 2016. Random intercepts were allowed for each site (parking areas and residential streets) sampled as well as for each basin within each site in order to account for any within-site and within-basin correlation. N =2,447 for all variables.

Effect	Rate Ratio	95% Confidence Interval	p
Rainfall (cm)	0.86	0.81-0.91	<0.001
Sediment (m^3)	1.34	0.46-3.97	0.59
Basin Depth (m)	0.89	0.53-1.49	0.66
Proportion of impervious surface surrounding basins within 10 m	0.19	0.03-1.09	0.06
Presence of three or more deciduous trees within 20 m of basin	7.79	2.83-21.44	<0.001
Basins located curbside	2.75	1.08-7.01	0.03

the sediment to the bottom of the sump. The radius of the sump vault was directly measured with a tape measure. The volume of sediment in the sump was estimated by calculating the area of the basin (using the radius of the basin sump) and multiplying that by the depth of sediment (measured from the top of the sediment layer to the sump bottom). These measurements were made during June, 2016, coinciding with the beginning of historically observed increased mosquito abundance in NSMAD catch basins during a typical mosquito season.

The proportion of area within a 10 m radius surrounding a basin that was impervious surface (e.g., asphalt, cement, roofs), whether three or more deciduous trees were present within 20 m of a basin were measured using the "ruler" tool in Google Earth Pro© and then were confirmed or modified based on on-site verifications. Deciduous trees were chosen for this parameter as they were expected to produce greater volumes of leaf debris over time than coniferous trees and were the most common type of tree near basins. The site characteristics are similar to those used to characterize "high- and low-intensity" urban areas of Kronenwetter-Koepel et al. (2005) and Stockwell et al. (2006). The location of basins in relation to curbs (curbside vs open pavement) was also investigated. Those basins not located directly adjacent to a curb were considered to be located in open pavement (>1 m from any curb). It was hypothesized that less organic material would be carried into basins that were further away from curbs. Weekly rainfall during the study period was compiled from publicly available data downloaded from the National Oceanic and Atmospheric Administration (NOAA) weather station located within the NSMAD operational area.

Data analyses

Statistical analyses were conducted using Stata™ 14.2, (StataCorp LP, College Station, TX). A univariable generalized linear mixed effects model was used to determine the multiplicative effect of a one unit increase in rainfall, sediment, basin depth, proportion of surrounding impervious surface, the presence of multiple trees, and if basins were curbside on the expected count of pupae. Random intercepts were allowed for each site (parking area and residential streets) sampled as well as for each basin within each site to account for any within-site and within-basin correlation. Because not all basins had complete data (i.e., car parked over lid and, most commonly, dry basins), the natural logarithm of the number of weeks each basin was sampled was treated as an offset. Over-dispersion of error variances was monitored using the ratio of the model's chi-square test-statistic over its degrees of freedom, and a negative binomial distribution was specified due to the presence of inflated zero counts. A log link was used to estimate the rate ratio.

RESULTS

All basins, except three shallower basins (<1.3 m in total depth) in Site 4, held water in sumps throughout the duration of the study. These three basins from Site 4 remained consistently dry from approximately the second half of the monitoring period. A total of 202 pupae were collected from parking area catch basins during the study period and were reared to adults for species identification. Of these, 196 (96.6%) were identified as *Culex pipiens/restuans* (121 males, 75 females), and six (4.4%) were *Ae. japonicus* (two males, four females). Thus, it is likely that most all of the pupae that were counted in the catch basins were *Culex pipiens* or *Cx. restuans* mosquitoes. Due to difficulties in distinguishing adult *Cx. restuans* from adult *Cx. pipiens*, these specimens were identified as *Culex pipiens/restuans*.

Pupae were observed in at least one basin in all the nine study sites except for Site 3 that had basins that never held any mosquitoes (larvae or pupae) during monitoring. The mean rate of productivity (pupae per basin-visit) over the 17 weeks of monitoring varied across sites, with the two most productive parking area sites (Sites 4 and 7) being located within forest preserves. (Figure 2). The mean rate of productivity in Sites 4 and 7 was a third or less of that of the residential street catch basins.

When taking the mean productivity over the 17-week study period, the 50 residential street catch basins in Site 9 were about 12 times more productive (mean pupae per basin-visit = 1.56 ± 0.12 SE, N = 813) than the basins from the other eight sites combined (mean pupae per basin-visit = 0.13 ± 0.02 SE, N = 1,634).

The parking area basins with lower productivity generally were deeper, held less sediment, were surrounded by more impervious surfaces and fewer trees, and were less often located curbside in comparison to street catch basins (Table 1). To investigate the effect of basin and site characteristics on pupal production over all 150 study basins, 2,447 basin-visits were examined (1,634 from parking area basins and 813 from residential street basins) in univariable analyses (Table 2). Of the five basin and site characteristics, the presence of three or more deciduous trees within 20 m of a basin and if basins were located curbside were both positively associated with mosquito productivity. Weekly rainfall and the proportion of impervious surface surrounding basins within 10 m were negatively associated with pupae. The total rainfall during the study period (62.3 cm) was like that of the same period of the previous six years (2015 = 64.5 cm, 2014 = 70.6 cm, 2013 = 60.3 cm, 2012 = 48.6 cm, 2011 = 82.6 cm, 2010 = 66.3 cm). Basin depth and sediment volume did not appear to be associated with pupal production.

DISCUSSION

As suspected, catch basins in parking areas were surrounded by more impervious surface and fewer trees, similar to the characteristics of the "high-density urban areas" described by Kronenwetter-Koepel et al. (2005) and Stockwell et al. (2006). And, similar to those previous studies, parking area sites held catch basins that produced mosquitoes at a rate of 30% or less than that of residential street catch basins which were surrounded by less impervious surface and more trees. The two forest preserve parking area sites contained the most productive basins of all the parking area sites. Although not reflected in our data, these sites are in properties that held the highest densities of trees (forests generally located 25-70 m away from basins), even in comparison to residential street sites.

In the current analyses, an important factor associated with pupal production in all catch basins (100 parking area and 50 residential curbside) appeared to be proximity to deciduous trees. In this current study, the rate of mosquito productivity from 150 basins was associated with an eight-fold increase by the presence of three or more trees nearby, a nearly three-fold increase if basins were located curbside. This suggests that fallen detritus from these trees is captured in basin sumps and that this captured organic detritus is associated with increased pupal abundance. The association with catch basin mosquito abundance and trees has been made elsewhere (Gardner et al. 2013). Certainly the close

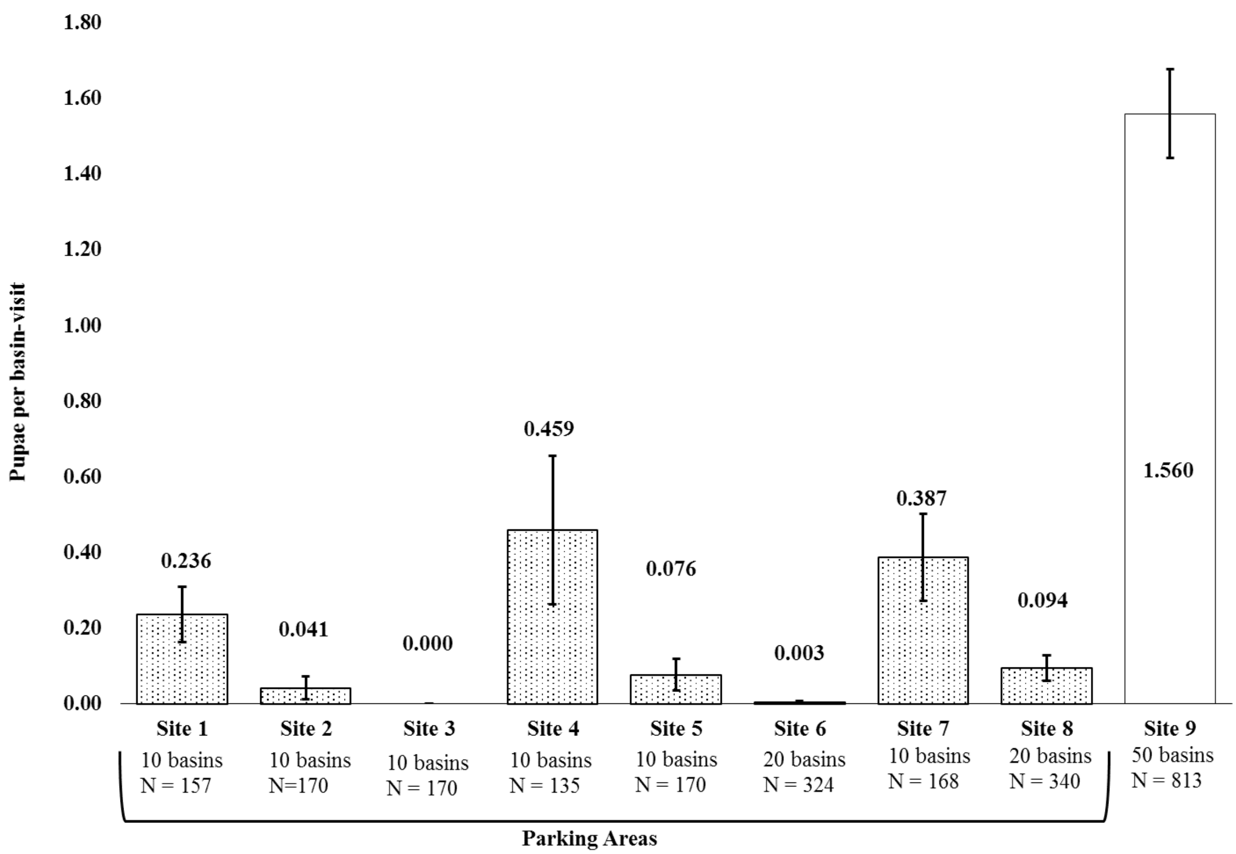

Figure 2. Mean pupae per basin-visit ± SE for 100 catch basins in eight different parking area sites (1-8) and 50 residential street catch basins (site 9) in the Northeast Chicago Metropolitan Area monitored with two dip samples weekly for 17 weeks from June to September, 2016.

proximity of multiple deciduous trees to basins may not always result in high productivity, however, identifying basins located close to deciduous trees could be useful to identify the risk for increased productivity. Likewise, the proportion of impervious surface surrounding basins may also influence productivity as well. Our model suggests the rate of mosquito productivity in the study basins was decreased by approximately 81% with each increased percent of surrounding impervious surface. Given the association with nearby trees and the expectation of less vegetation and trees with increasing impervious surfaces, it can be expected that an association with the amount of surrounding impervious surfaces with mosquito productivity will be observed.

Also, as long noted, rainfall appeared to reduce the rate of productivity of basins (with each cm of rainfall reducing the rate by 14%). Rainfall events are commonly associated with temporary reductions of mosquitoes in catch basins due to inflows flushing mosquitoes out of these structures (Maddock et al. 1963, Covell and Resh 1971, Munstermann and Craig 1977, Hamer et al. 2011, Rey et al. 2006, Stockwell et al. 2006, Gardner et al. 2012). Of most practical use to mosquito control programs, however, is the reduced mosquito productivity observed in parking area basins. These findings suggest that for most of these common sites, reduced larvicide applications to basins may be a reasonable policy for many mosquito control programs. Based on the results of this study, the NSMAD will remove 2,000 basins from regular larvicide treatments. This would result in a potential cost-savings in reduced labor and larvicide of $6,000 to $20,400 per round of larvicide treatments, depending on the larvicide used. Certainly more research is needed to confirm this trend in parking area sites elsewhere and in more sites.

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REFERENCES CITED

Anderson, J.F., F.J. Ferrandino, D.W. Dingman, A.J. Main, T.G. Andreadis, and J.J. Becnel. 2011. Control of mosquitoes in catch basins in Connecticut with *Bacillus thuringiensis israelensis*, and spinosad. J. Am. Mosq. Contr. Assoc. 27: 45-55.

Barrera, R., M. Amador, and G.C. Clark. 2006. Use of the pupal survey technique for measuring *Aedes aegypti* (Diptera: Culicidae) productivity in Puerto Rico. Am. J. Trop. Med. Hyg. 74:290-302.

Carpenter, S.R. 1983. Resource limitation of larval treehole mosquitoes subsisting on beech detritus. Ecology 64: 219-223.

Covell, C. V. and V. H. Resh. 1971. Relative abundance of *Culex pipiens* and *Culex restuans* in catch basins in Jefferson County, Kentucky. Mosq. News 31: 73-76.

Gardner, A.M., G.L. Hamer, A.M. Hines, C.M. Newman, E.D. Walker, and M.O. Ruiz. 2012. Weather variability affects abundance of larval *Culex* (Diptera: Culicidae) in storm water catch basins in suburban Chicago. J. Med. Entomol. 49: 270-276.

Gardner, A.M., T.K. Anderson, G.L. Hamer, D.E. Johnson, K.E. Varela, E.D. Walker, and M.O. Ruiz. 2013. Terrestrial vegetation and aquatic chemistry influence larval mosquito abundance in catch basins, Chicago, USA. Parasit. Vectors 6: 9.

González, R. and M.F. Suárez MF. 1995. Sewers: the principal *Aedes aegypti* breeding sites in Cali, Colombia. Am. J. Trop. Med. Hyg. 53: 160.

Hamer, G.L., P.H. Kelly, D.A. Focks, T.L. Goldberg, and E.D. Walker. 2011. Evaluation of a novel emergence trap to study *Culex* mosquitoes in urban catch basins. J. Am. Mosq. Contr. Assoc. 27: 142-147.

Harbison, J.E., M.E. Metzger, W.E. Walton, and R. Hu. 2009. Evaluation of factors for rapid development of *Culex quinquefasciatus* in belowground stormwater treatment devices. J. Vector Ecol. 34: 182-190.

Kronenwetter-Koepel T.A., J.K. Meece, C.A. Miller, and K.D. Reed. 2005. Surveillance of above- and below-ground mosquito breeding habitats in a rural Midwestern community: baseline data for larvicidal control measures against West Nile virus vectors. Clin. Med. Res. 3: 3-12.

Maddock, D. R., C. M. Elmore J, R. and H. F. Schoof. 1963. Preliminary tests with DDVP vapor for the control of *Culex pipiens quinquefasciatus* in catch basins. Mosq. News 23: 59-74.

Manrique-Saide, P., C. Arisqueta-Chablé, E. Geded-Moreno, J. Herrera-Bojórquez , U.C. Valentín, J. Chablé-Santos, A. Che-Mendoza, E.C. Sánchez, J.I. Arredondo-Jiménez, and A. Medina-Barreiro. 2013. An assessment of the importance of subsurface catch basins for *Aedes aegypti* adult production during the dry season in a neighborhood of Merida, Mexico. J. Am. Mosq. Contr. Assoc. 29: 164-167.

Merritt, R.W., R.H. Dadd, and E.D.Walker. 1992. Feeding behavior, natural food, and nutritional relationships of larval mosquitoes. Annu. Rev. Entomol. 37: 349-376.

Molaei, G., T.G. Andreadis, P.M. Armstrong, R. Bueno Jr, J.A. Dennett, S.V. Real, C. Sargent, A. Bala, Y. Randle, H. Guzman, A. Travassos da Rosa, T. Wuithiranyagool, and R.B. Tesh. 2007. Host feeding pattern of *Culex quinquefasciatus* (Diptera: Culicidae) and its role in transmission of West Nile virus in Harris County, Texas. Am. J. Trop. Med. Hyg. 77: 73-81.

Munstermann, L.E. and G.B. Craig Jr. 1977. *Culex* mosquito populations in the catch basins of northern St. Joseph County, Indiana. Proc. Indiana Acad. Sci. 86: 246-252.

Prioteasa, L.F., S. Dinu, E. Fălcuţă, and C.S. Ceianu. 2015. Established population of the invasive mosquito species *Aedes albopictus* in Romania, 2012-14. J. Am. Mosq. Contr. Assoc. 31: 177-181.

Rey, J.R., G.F. O'Meara, S.M. O'Connell, and M.M. Cutwa-Francis. 2006. Factors affecting mosquito production from stormwater drains and catch basins in two Florida cities. J. Vector Ecol. 31: 334-343.

Rydzanicz, K., P. Jawień, E. Lonc, and M. Modelska. 2016. Assessment of productivity of *Culex* spp. larvae (Diptera: Culicidae) in urban storm water catch basin system in Wrocław (SW Poland). Parasitol. Res. 115: 1711-1720.

Stockwell, P.J., N. Wessell, D.R. Reed, T.A. Kronenwetter-Koepel, K.D. Reed, T.R. Turchi, and J.K. Meece. 2006. A field evaluation of four larval mosquito control methods in urban catch basins. J. Am. Mosq. Contr. Assoc. 22: 666-671.

Suárez-Rubio, M. and M.E. Suárez. 2004. The use of the copepod *Mesocyclops longisetus* as a biological control agent for *Aedes aegypti* in Cali, Colombia. J. Am. Mosq. Contr. Assoc. 20: 401-404.

Vallorani, R., P. Angelini, R. Bellini, M. Carrieri, A. Crisci, S. Mascali Zeo, G. Messeri, and C. Venturelli. 2015. Temperature characterization of different urban microhabitats of *Aedes albopictus* (Diptera: Culicidae) in Central-Northern Italy. Environ. Entomol. 44: 1182-1192.

Walker, E.D. and R.W. Merritt. 1988. The significance of leaf detritus to mosquito (Diptera: Culicidae) productivity from treeholes. Environ. Entomol. 17: 199–206.