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We Want *You* to Fight Stormwater Mosquitoes

A call for interagency and interdisciplinary collaboration

By Justin E. Harbison and Marco E. Metzger

Mosquitoes are annoying. No joke. A single mosquito flying around your bedroom when you are trying to sleep can literally test your mental and emotional limits. While one is bad enough, a swarm of mosquitoes can lead to outright panic. What's more, many species have embraced the urban lifestyle, using sources of standing water we've intentionally or unintentionally created as nurseries for their larvae. And, as you might guess, this includes water found within modern infrastructure engineered to manage stormwater runoff. In fact, in many urban areas, there is some evidence that stormwater infrastructure may be the single greatest source of mosquitoes (Harbison et al. 2010). With these rather disturbing visuals in place, we present an argument for increased collaboration between stormwater and mosquito control agencies to improve our chances against these irritatingly persistent foes.

The Rich History Between Stormwater and Mosquitoes

It is easy to understand why agencies tasked with the admirable and difficult jobs of floodwater management and stormwater pollution prevention would be frustrated by spoilsports claiming that certain engineered structures are perfect places for producing mosquitoes. Someone always has to complain. However, the stormwater community should take some comfort in knowing these concerns are not due to a growing conspiracy of mean-spirited people

THE BMP PARADOX

The number of structural stormwater treatment best management practices (BMPs) installed in urban areas is rapidly increasing as cities scramble to meet requirements of their National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges. The paradox lies in the fact that although BMPs are designed to mitigate harmful effects of stormwater on both human and environmental health, many of these structures hold temporary or permanent bodies of standing water that are ideal for the development of potentially disease-carrying mosquitoes. Production of mosquitoes is highly variable, often localized, and dependent on many factors, but contrary to popular belief, it can often be greatest in physically smaller BMPs. As the number of BMPs increases, so does the likelihood of creating new sources of mosquitoes.

in the field of mosquito control. Stormwater structures are highly susceptible to mosquito production, and the battle against these opportunistic six-legged flying syringes has raged on for over a century in the United States in the fight to protect public health and quality of life.

Since the discovery of mosquitoes' ability to transmit diseases in the late 1800s, stormwater structures have been implicated in aiding the spread of malaria, yellow fever, dengue, and other diseases in many urban areas of the United States. The most well-known, recent connection was made shortly after the discovery of West Nile virus (WNV) in New York City in 1999.

Headlee 1945

Figure 1. Mosquito control specialist in the 1940s sampling mosquitoes from a street drainage catch basin in New Jersey

Chase and Nyhen 1903

Figure 2. Application of kerosene to catch basins to control mosquitoes in Brookline, MA, circa 1900

A mosquito species common to the city's storm drains and catch basins was identified as the primary disease vector throughout the region (Spielman and D'Antonio 2001). Over the next five years, WNV spread rapidly across North America, and numerous other mosquito species associated with urban stormwater infrastructure were incriminated in spreading the disease (Irwin et al. 2008, Metzger et al. 2008, Calhoun et al. 2007, Gingrich et al. 2006). This is not entirely surprising, because historical data have documented mosquitoes in cisterns, rain barrels, flood control channels and impoundments, storm drains, catch basins (Figures 1 and 2), combined sewage overflows, and, most recently, structural stormwater best management practices (BMPs) (Figures 3 and 4). Cumulatively, more than 40 mosquito species have been identified from these structures (Harbison et al. 2010).

Few realize that during the first half of the 20th century, civil and environmental engineers were among the greatest proponents and leaders of mosquito control efforts in the United States and abroad. This idea is exemplified by the historic work of Joseph LePrince, a sanitary engineer. LePrince performed groundbreaking work controlling mosquitoes responsible for outbreaks of malaria and yellow fever during construction of the Panama Canal (Figure 5) and during World War I. Later, in the 1930s, engineers and mosquito control experts in the Tennessee River Valley worked together in a highly successful malaria control program by both managing water levels and applying insecticide to problem areas (Spielman and D'Antonio 2001). The structural and hydrological expertise of engineers directing or collaborating in these efforts led to tremendous advancements in mosquito control, which eventually helped eradicate malaria and yellow fever from the United States.

The Need for Greater Collaboration

Unfortunately, much of the history between stormwater and mosquito control specialists has been obscured by time, and despite repeated proposals for collaboration in published literature, joint ventures between these two disciplines remains relatively uncommon. In light of modern clean water regulations, recent studies yet again have suggested a need for greater interagency and interdisciplinary collaboration to better prevent the spread of mosquitoes and mosquito-borne diseases (Metzger et al. 2008, Harbison et al. 2010). The importance of collaborative work is significant, particularly if one considers the growing potential for exotic mosquitoes and mosquito-borne diseases to be introduced into the United States as international travel and trade increases. The impact of WNV over the past decade was a wakeup call to many people in this regard. However, foreign species of mosquitoes continue to be introduced into the US, including one potential disease vector that has already been found in stormwater BMPs on the East Coast (Linthicum et al. 2003, Gingrich et al. 2006). While it may not always be in the public's eye, the threat to health and quality of life created by mosquitoes still exists and cannot be ignored.

Assessing Mosquitoes and BMPs in the 21st Century

The recent proliferation of stormwater BMPs in urban areas has created widespread concern among mosquito control agencies who view these structures as potentially adding to the mosquito burden generated from the already highly productive stormwater infrastructure. The need for more in-depth information prompted the California Department of Public Health Vector-Borne Disease Section (VBDS) to conduct a nationwide survey of state and local government agencies responsible for mosquito surveillance and control and/or stormwater management (Harbison et al. 2010). The objectives of the survey were to assess the prevalence of BMPs and associated mosquito production, identify current measures taken to control mosquitoes within BMPs, and elucidate the extent of collaboration between these agencies.

Agencies surveyed by VBDS included special districts and city, county, and state entities (Figure 6) with varying land use jurisdictions: urban, 38.3%; suburban, 12.5%; rural, 16.4%; a combination of two, 15.2%; and a combination of all three, 17.6%.

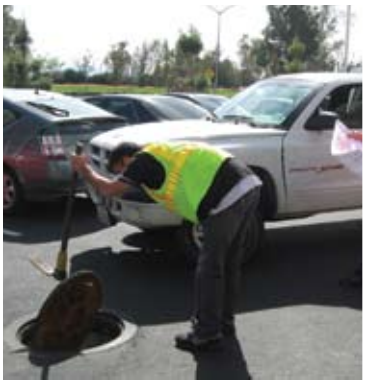
In total, 329 agencies participated in the study, with nearly equal representation of stormwater and mosquito control from all 50 states and the District of Columbia (Figure 7). (The "Other" category shown in Figure 6 consists of six combined city/county agencies, three private companies hired to perform either mosquito control or stormwater activities for local governments, and one agency that declined to provide this information.)

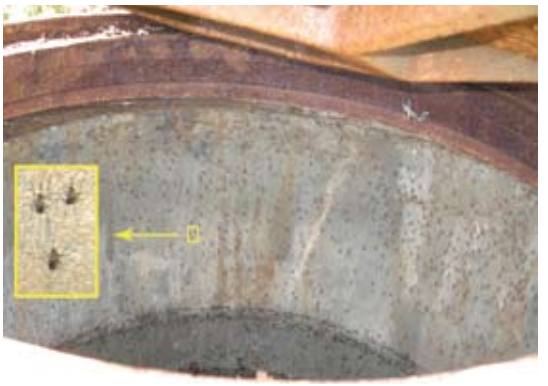
Not surprisingly, agencies from every state (312 of 329 agencies, or 95%) reported BMPs within their jurisdictions, and the presence of mosquitoes was reported within these structures in nearly every state. Only in Maine and Washington DC (with two and one participating agencies, respectively) were there no agencies reporting mosquito production within their BMPs. This reported lack of mosquitoes is likely due to the small number of agencies surveyed in these two regions rather than to any unique difference in mosquito behavior or BMPs in those areas of the United States. Obviously, mosquitoes don't follow political boundaries, and different species can thrive in conditions as cold as those in Alaska and Minnesota and as hot and dry as those in southern California, Texas, and Arizona.

Responses to the survey also suggest that most types of BMPs can support mosquito production. The seven categories of BMPs reported to harbor mosquitoes included detention and/or retention basins, grass swales, stormwater treatment wetlands/ponds, infiltration basins/trenches, belowground proprietary systems, and bioretention systems. This information corroborated previous findings in California by VBDS (Metzger et al. 2002) and clearly indicates BMPs can and do create mosquito habitat throughout the United States.

The Current State of Collaboration

Overall, approximately 40% of survey participants reported some degree of interagency collaboration to minimize mosquito production in BMPs. Among three agency categories (stormwater, mosquito control, or both), those that perform both mosquito control and stormwater activities are more likely to collaborate with other agencies than those that perform only one of these two functions. These multifunctional agencies were able to list the number of BMPs within their jurisdiction significantly more often than were mosquito control agencies, and they were aware of mosquito production within their BMPs and knew whether their BMPs were routinely monitored for mosquitoes significantly more often than did stormwater agencies. This greater breadth of knowledge was no doubt a result of the dual nature of these programs but may also have been boosted through relationships with outside agencies.





Left: Figure 3. Monitoring standing water for mosquitoes in a stormwater treatment system in Ontario, CA. Despite over a century of technological advancements, including air travel, space exploration, and the Internet, we still use pick-axes to remove manhole covers.
Right: Figure 4. Recently emerged adult mosquitoes resting on the sides of an inspection manhole of a hydrodynamic separator in Perris, CA

It may seem odd that an agency already performing both mosquito control and stormwater activities would need or even want to collaborate with other agencies, particularly as these agencies likely have staff with expertise in both disciplines. The answer to this may be linked to frequently overlapping jurisdictional boundaries of city, county, and state agencies with stormwater programs. For example, a city public works department, county flood control district, and state department of transportation may all have BMPs (and other stormwater structures) installed and operating within the city's limits. If the city public works department also performs mosquito control (and therefore is likely to self-identify as an agency performing "both" functions), this department would require access to all stormwater structures within the city boundaries regardless of ownership, thereby making it necessary to collaborate with outside agencies. Independent mosquito control programs similarly require access to stormwater structures, strongly suggesting that the need for interagency collaboration exists for these agencies as well; however, this assumption was not supported by the questionnaire responses. A significantly smaller percentage of mosquito control agencies (44 of 118, or approximately one third) reported collaboration when compared to almost 60% (33 of 56) of multifunctional agencies. The reason for this is unclear, but it is possible that the educational diversity of staff from multifunctional agencies makes it easier to develop contacts and facilitates collaborative efforts with outside agencies. Regardless, the fact that more multifunctional agencies were able to report critical information regarding both BMPs and mosquitoes underscores the potential benefits resulting from interagency and interdisciplinary work and supports the long-suggested calls for collaboration.

Program Weaknesses and Attitudes Uncovered by the Survey

When you consider the close association between stormwater and mosquitoes, it comes as no shock that mosquitoes were reported in BMPs nationwide by participating agencies. However, responses revealed a number of unexpected program weaknesses and apathetic attitudes that could create barriers to interagency collaboration and compromise mosquito control efforts. Approximately half the agencies perform-

Orenstein 1912

Figure 5. Laborers controlling mosquito larvae by applying crude oil to roadside drainage ditches in the Panama Canal Zone using a pipe apparatus, circa 1912

ing stormwater management (either solely or with mosquito control activities) were unable to state 1) how many BMPs were in their jurisdiction and 2) how often these BMPs were maintained. Because stormwater agencies are often tasked with planning, permitting, installing, and/or maintaining BMPs, one might assume this information is not only easily available to these agencies, but is in fact generated by them. From the mosquito control perspective, knowing the locations of and having access to these potential sources of mosquitoes is critical to adequately control or prevent the spread of mosquitoes. The reported lack of information related to BMP maintenance also raises some concerns. Seeing that BMPs are properly maintained (e.g., removing accumulations of sediment and trash) not only can help minimize mosquito problems, but is necessary to ensure that the water-quality function of these structures is preserved (Metzger et al. 2008). Everybody wins when BMPs are maintained.

Another surprise was the perceived importance of mosquito control to stormwater agencies. When asked to consider the potential benefits of collaboration, one quarter of stormwater agencies reported improved mosquito prevention would be an outcome that is "not important." This apparent lack of appreciation for mosquito control activities is somewhat disconcerting, especially when one considers the decades of compelling evidence supporting the public health value of such programs and the critical role civil and environmental engineers played in early mosquito control efforts. The prevention of death, disease, and discomfort achieved through organized mosquito control has been widely recognized for over a century, and its value continues to be seen worldwide (Spielman and D'Antonio 2001). It is important for the stormwater community to recognize the risks posed by mosquitoes and the need to manage their populations in urban environments. This shouldn't be too much of a stretch, considering the Clean Water Act (the impetus for modern stormwater programs) is built largely on a foundation of public health, requiring waters to be both "fishable and swimmable." Protecting the public from fecal coliform or from eating tainted fish only to increase the risk of mosquito-borne disease suggests a situation where neither stormwater nor mosquito control agencies are meeting their goals. It may seem like a Catch-22, where anything you do can result in people getting sick, but it has been shown that addressing the concerns of both stormwater and mosquito control communities can help both sides meet their needs and sometimes even improve programs and attitudes (Metzger et al. 2008).

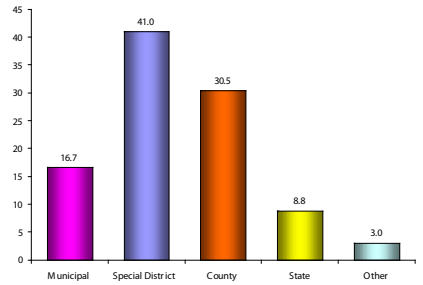


Figure 6. Percentage of 329 government agencies, grouped by category, that were surveyed nationwide regarding mosquito production in structural stormwater BMPs. The "Other" category consisted of six combined city/county agencies, three private companies hired to perform either mosquito control or stormwater activities for local governments, and one agency that declined to provide this information.

Figure 7. Approximate geographic location of the 329 government agencies that participated in the VBDS survey investigating mosquito production in structural stormwater BMPs

As an example, local mosquito control agencies may be willing to assist stormwater programs by notifying staff of structures that are malfunctioning and/or are in need of maintenance, especially given that it would also be in their own interest to keep BMPs functioning properly and to minimize standing water. The increased attention given to BMPs could help identify possible issues (e.g., overgrown vegetation, clogged structures) before they create serious and likely expensive problems. And, in many cases, just the threat of mosquitoes can promote proper and timely maintenance of BMPs. For example, a homeowners association might be more likely to maintain a detention basin servicing a subdivision if that association and its residents have a better understanding of the connection between these types of structures and mosquitoes. When you consider the growing need to do more with fewer resources, having a little outside help never hurts.

Moving Forward With Collaboration

Results of the survey overwhelmingly suggest a need for greater collaboration. In fact, about 70% of those participating agencies that reported collaborating to minimize mosquitoes in BMPs stated that more or improved collaboration was needed. Based on these findings, we still have a way to go. However, the future is not entirely bleak, and the survey did uncover some ideas to help jumpstart collaborative work. The two most common suggestions to improve collaboration between stormwater and mosquito control agencies were 1) to increase interagency communication, and 2) to raise awareness of the association between stormwater and mosquitoes. The key to addressing either of these suggestions lies in communication. As such, the most elementary approach the stormwater community can use to take the initiative for building collaborative relationships is picking up the telephone.

The potential impact of a simple phone call should never be underestimated. Even if a full-blown working relationship does not result from a phone conversation, shared information can go a long way to help develop an understanding and appreciation for the roles and responsibilities of other agencies, particularly those with overlapping or arguably conflicting goals. At a minimum, a mosquito control agency can provide good advice on keeping irritating insects from ruining your next family outing. Collaborating with mosquito control agencies doesn't have to be a frightening prospect and really shouldn't be motivated by fear or financial worries. Protecting people and the environment from polluted waters and preventing the spread of mosquitoes and their diseases are both worthy pursuits and are important to the public's well-being. Neither needs to take precedence over the other when both sides can work together.

FUN FACT: BMP

Although the ambiguous term "best management practice" or BMP was adopted by politicians and legislators in the 1970s in reference to actions, practices, and structures used to reduce flow rates and constituent concentrations in runoff, it has been used increasingly to describe a myriad of practices, from production of peanuts to patient care in hospitals. Even mosquito control has jumped on the BMP bandwagon (Harbison et al. 2010). Yes, we now have BMPs for minimizing mosquitoes in BMPs. Is it time to retire this term yet?

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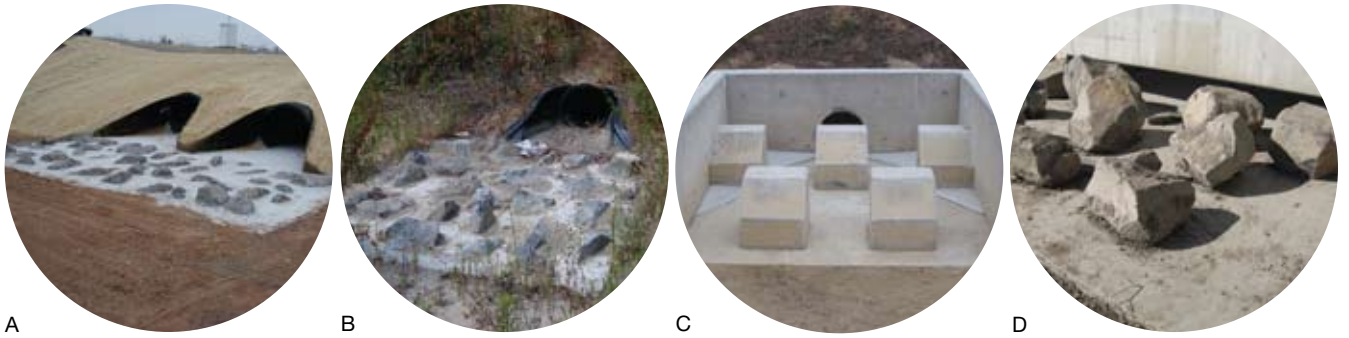
CALTRANS AND VBDS: A DECADE-LONG CASE STUDY IN COLLABORATION

For many stormwater agencies, there may be few obvious incentives and more headaches involved when considering whether to collaborate with local mosquito control agencies. However, the relationship between the California Department of Transportation (Caltrans) Stormwater Program and California Department of Public Health Vector-Borne Disease Section (VBDS) provides an example of how collaboration can be worth the effort. Since 1999, VBDS has worked closely with Caltrans to develop long-term, non-chemical solutions to reduce mosquito

Figure 8. For over a decade, VBDS staff has monitored mosquito populations in over 100 Caltrans BMPs in various parts of California to identify problem areas likely to produce mosquitoes and to develop non-chemical preventive solutions. Some examples illustrating the diversity of structures examined include (A) a multi-chambered treatment train in Los Angeles County, (B) a gross solids removal device in Orange County, (C) a stormwater treatment system in San Diego County, and (D) a traction sand trap in the Lake Tahoe Basin.

Figure 9. Four examples of loose rock riprap installed to dissipate water energy at the inlets of detention basins. This common feature consistently provided suitable mosquito habitat because of its propensity to hold standing water for longer than four days.



A B C D

Figure 10. Alternative inlet designs installed by Caltrans in attempts to mitigate persistent mosquito habitat associated with loose rock riprap. Although not entirely fail-proof, each of the alternate designs (A, B: rock embedded in a concrete apron, C: cast concrete blocks, and D: boulders placed on top of a concrete apron) was far superior to the loose riprap and rarely resulted in mosquito production.

production in Caltrans's structural stormwater BMPs. The decade-long working relationship has raised awareness, improved maintenance schedules, and led to the retrofit of many structures with features less likely to hold standing water (Figures 8, 9, and 10). These efforts have potentially reduced the risk of mosquitoes and disease to residents and visitors of surrounding areas while improving water quality through improved maintenance of BMPs.

Some of the significant findings from the VBDS-Caltrans collaboration include:

- Most BMP designs had potential to hold standing water and produce mosquitoes, regardless of their water treatment function.
- Mosquitoes were often found year-round in BMPs, although their presence was difficult to predict for many reasons, including the occurrence of unexpected non-stormwater flows.
- The wide range of habitats created in BMPs allowed for production of many different mosquito species. Seventeen species were documented in California, including several capable of carrying diseases. The two most common species found in BMPs are also the most important vectors of West Nile virus in the state.
- Most BMPs were located within 500 meters of residential, commercial, and recreational areas, well within the flight distance of many mosquito species, reinforcing the fact that these structures can present a public health concern.

Recommendations made by VBDS to minimize mosquitoes in BMPs include the following:

- Stormwater can be detained for as long as four days without creating a mosquito concern throughout California. Water can be held indefinitely between October and April in certain high-altitude areas of the Sierra-Nevada greater than 5,000 feet (e.g., Lake Tahoe Basin) due to the harsh alpine climate lethal to larvae of disease-carrying mosquitoes.
- Replace loose rock riprap (Figure 9) with designs less prone to hold water for longer than four days (Figure 10).
- Install tight-fitting covers and manhole cover inserts to minimize mosquito access to permanent sources of standing water in certain belowground BMPs.
- Maintenance and monitoring of BMPs should be proactive and include frequent inspections, particularly following rain events or where non-stormwater runoff is common.
- Aggressively trace and eliminate sources of non-stormwater runoff, including those that originate from other properties.
- Notify local mosquito control agencies of the locations of all new and current BMP structures to ensure mosquito concerns are addressed.