URBAN Waterways

Mosquito Control for Stormwater Facilities

Stormwater engineers and best management practice (BMP) designers must evaluate and balance many goals when designing stormwater facilities. Among these are flood control, water quality, stream health, aesthetics, and mosquito control. A recent increase in mosquito-borne diseases, such as West Nile, encephalitis, and eastern equine encephalomyelitis, has provoked public concern about mosquitoes in stormwater facilities.

This publication summarizes some key facts that stormwater engineers and BMP designers should know as they design facilities and implement mosquito control measures. It also provides an overview of strategies for limiting mosquito populations in stormwater facilities.

MOSQUITO POPULATIONS IN STORMWATER IMPOUNDMENTS

Several studies conducted across the United States have evaluated mosquito presence in stormwater facilities. Although the findings from these studies vary, as noted below, they document the presence of mosquitoes in many stormwater practices.

- A 1979 study of 35 impoundments in New Jersey found mosquitoes present in 80 percent of the sampled wet ponds, dry ponds, and infiltration devices, such as sand filters. Mosquitoes were nearly as likely to be present in detention facilities (dry ponds), retention facilities (wet ponds), and infiltration devices.
- A 1987 study in Illinois found very high mosquito counts in catch basins such as street inlets. This was attributed to both a lack of predators and a large amount of organic material in the basins studied. Accumulation of organic material is a common indicator of mosquito populations as it provides refuge from predators.
- A 1993 study of 238 impoundments in Florida found mosquitoes present in nearly 90 percent of the sampled wet ponds, dry ponds, and infiltration basins.
- A 2004 study of 52 impoundments in North Carolina found *no* mosquito larvae or pupae in more than 66 percent of the facility samples.

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It should be noted, however, that mosquito numbers were somewhat below average due to a relatively cool summer. In this study, the average number of mosquitoes collected per sample from any catch basin was higher than the highest number collected per sample from any impoundment. Wetlands and innovative wet ponds (ponds with wetland zones) were more likely than standard wet ponds to have a higher number of mosquito species.

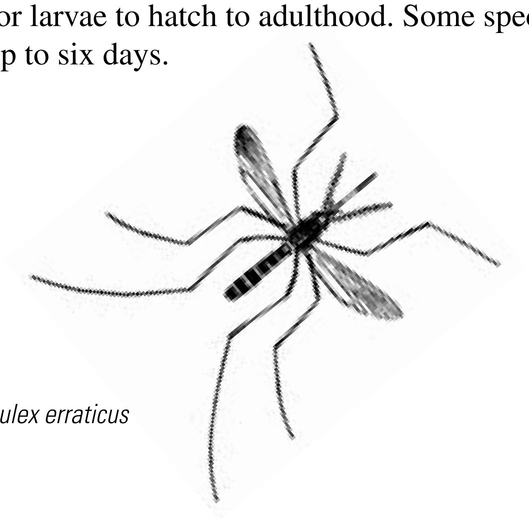
- Informal observations in North Carolina indicate that sand filters often will not serve as mosquito breeding grounds because of the oil sheen that typically forms on top of the sedimentation chamber. The oil sheen interferes with the ability of mosquito larvae and pupae to breathe oxygen.
- Studies in Australia and the United States have indicated that polluted water, such as water containing oil residuals, impedes mosquito growth.

The resources on the recommended reading list provide detailed information about studies conducted on mosquito populations in stormwater facilities.

MOSQUITO TYPES AND ASSOCIATED DISEASES

All mosquitoes have two common requirements: They need water to complete their life cycle, and the larval and pupal stages must breathe oxygen. Some species can obtain oxygen from aquatic plants.

There are two main types of mosquito species: those that live in *permanent and semi-permanent* waters and those that live in *temporary waters*. Permanent and semi-permanent waters are found in a pond or wetland, where they are present except during drought periods. Pools of water that accumulate in low-lying areas during and immediately following a flood are examples of temporary waters. Mosquitoes need a minimum of four consecutive days of stagnant water for larvae to hatch to adulthood. Some species require up to six days.



Culex erraticus

Typically, the mosquito species that live in permanent and semi-permanent waters are those of concern in stormwater wetlands and wet ponds. In general, permanent-water species lay eggs directly on the water's surface. Their eggs hatch in about two to three days. A few species of permanent-water mosquitoes obtain oxygen directly from aquatic plants (for example, from *Typha* spp., commonly known as cattails). The three most dominant species found in the North Carolina study were permanent-water species: *Culex erraticus* (present in 18 percent of the N.C. facilities tested), *Anopheles quadrimaculatus* (9.4 percent), and *Anopheles punctipennis* (5.6 percent).

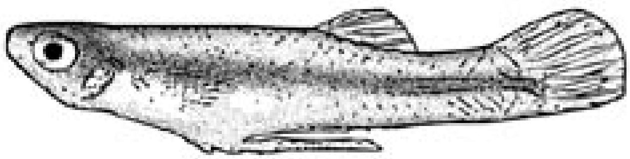
Temporary-water mosquito species, which include floodwater species, lay eggs in moist areas and wait for occasional floodwaters to inundate the eggs. Once this happens, eggs hatch and mosquito growth begins. Not surprisingly, infiltration devices harbor a relatively large percentage of floodwater species. As infiltration devices slowly clog due to age and lack of maintenance, they can retain water long enough to allow floodwater mosquito pupae and larvae to reach maturity. The most common floodwater species in the 2004 North Carolina study was *Aedes vexans*, which was found in 3.2 percent of all facilities tested.

All the mosquito species found in the North Carolina study (14 in total) are known to be carriers of the West Nile virus. The mosquito found most often and in the greatest numbers in N.C. stormwater facilities, *Culex erraticus*, is a *vector* for the eastern equine virus: the mosquito carries the virus without being affected by it.

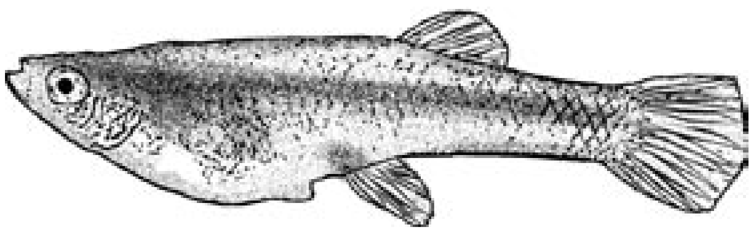
This species feeds on both birds and mammals. Some birds are carriers for both West Nile and eastern equine viruses. Once a mosquito is infected by feeding on a bird that carries the virus, it can transmit the virus to large mammals (such as horses and people) when it takes another blood meal.

MOSQUITOFISH AND OTHER PREDATORS

Research indicates that some ecological or biological controls can limit mosquito populations with varying degrees of success. In particular, mosquitofish (*Gambusia affinis*) are extremely effective at limiting mosquito population growth. *Gambusia affinis* is native to North Carolina, and the subspecies *holbrooki* occurs in the N.C. mountains. Mosquitofish are amazingly tolerant. They can survive temperatures ranging from 33ºF to more than 100ºF. In addition, they can survive in a wide pH range (5 to 9.5) and in salinities as high as 15 parts per million (ppm).



Male Mosquitofish *(Gambusia affinis)*



Female Mosquitofish *(Gambusia affinis)*

Perhaps most amazing, the mosquitofish can live with dissolved oxygen levels of nearly 0.0 ppm. Its resilience in a wide range of environments makes the mosquitofish a good biological control for mosquitoes in some environments. Research in North Carolina indicates that sampled ponds and wetlands with mosquitofish present had significantly fewer occurrences of mosquitoes than those without the fish.

Because mosquitofish are resilient omnivores, however, they can have a detrimental impact on the diversity of a wetland or wet pond system. Their effect on populations of beneficial aquatic invertebrates—the many small insects, snails, and worms that nourish fish and other wildlife—is still being debated. Nevertheless, mosquitofish introduction is currently the only fail-safe ecological measure for limiting mosquito population growth. Some predators, such as bats and purple martins, simply cannot eat enough mosquitoes to make any noticeable reductions. Moreover, purple martins have been found to eat another voracious mosquito predator, the dragonfly.

LOCATING BMPS TO LIMIT MOSQUITO IMPACT

Another mosquito control involves where a stormwater facility is located. Before a stormwater practice is designed and installed, the site should be considered. The facility should be located where any potential increase in the mosquito population is less likely to become a noticeable problem.

Select locations for stormwater practices where mosquitoes already live (such as a ditch). If a relatively large mosquito population exists in one part of the property but not in another, locate the BMP in the area where mosquitoes are already present. That way the BMP will not add a new mosquito habitat. This typically will not be an issue because most stormwater wetlands and wet ponds are located in the lowest and wettest part of the property to be cost-effective to the developer.

WETLAND AND WET POND DESIGN AND MANAGEMENT

Stormwater BMP designers can incorporate design features and management strategies inside stormwater wetlands and wet ponds that will limit mosquito growth.

Design features. The most common design feature is the use of *deep pools* to encourage mosquito predators and water flow. Deep pools are integral to wetland design if mosquito control is a concern (Figure 1). Pools need to have a minimum water depth of 18 inches for mosquitofish survival. In this case, deeper is better; a 30-inch depth is preferable. Deep pools should be incorporated more frequently than has been traditionally prescribed. Several small deep pools will give mosquitofish easy access to shallow vegetation zones.

Deep pools can also act as level spreaders when placed where they are perpendicular to the flow of water. When oriented perpendicularly to the main flow path, pools can help maintain sheet flow. This allows more surface area of the stormwater wetland or wet pond to receive flow. Flowing water is almost never likely to become a breeding site for mosquitoes.

In contrast, *shallow pond zones* (1 to 3 inches deep) that are *disconnected* from the general flow path are a potential mosquito habitat. If the shallow pools typically dry out in three to four days, the likelihood that mosquito larvae will survive and emerge as adults will be reduced. In addition, having isolated shallow areas that intersect the shallow water table should be avoided if these shallow areas are not accessible to fish from a deep pool.

FIGURE 1. Deep pools are an integral part of mosquito control in stormwater wetland design. They provide homes to mosquito predators such as *Gambusia affinis* (mosquitofish).

Management strategies. Some studies have shown that a water-level drawdown of just 2 to 3 inches can significantly reduce mosquito populations. Because of this, prescribed drawdowns may effectively reduce mosquito populations. But this level of management is probably feasible only for very large stormwater wetlands and wet ponds with multiple-acre surface areas. This technique is commonly employed in wastewater treatment wetlands. A stormwater wetland and wet pond are designed for an occasional flood and drawdown. It is unclear what the impact of a typical stormwater wetland or wet-pond flooding and post-storm drawdown would be on mosquito populations.

Other facility concerns. Increased age and a lack of maintenance make stormwater facilities more likely to be mosquito sources than new and well-maintained facilities. This is probably due to the growth of vegetative species that are undesirable for mosquito control, as discussed in the vegetation section. Simple maintenance strategies, such as removal of unwanted plant species on an annual basis, are strongly recommended.

VEGETATION

Some types of vegetation help with mosquito control, while others exacerbate mosquito problems. Certain species of plants should be avoided in the initial planting plans for stormwater wetlands and wet ponds. As the facilities age, these same species may need to be removed on a regular basis, such as one time per year. Guidelines for select vegetation removal are found at: www.bae.ncsu.edu/stormwater.

Avoid a wooded overstory. A main finding from the N.C. study was that the presence of woody plants in wetlands and wet ponds always corresponded to the presence of mosquitoes (Figure 2). This has important maintenance implications. One especially common woody species in North Carolina that will need to be removed is *Salix nigra* (black willow). This tree encourages mosquitoes because it provides shade and collects organic debris at its base, which serves as a refuge for mosquitoes from predators. Certain herbaceous species of plants, however, have been identified as being attractive to mosquito predators, such as dragonflies. Some of these plants may also allow easier fish migration into the inner vegetation zones. Researchers recommend the following vegetation species:

FIGURE 2. Wooded stormwater wetlands and woody fringes along wet ponds provide excellent mosquito habitat and should be avoided.

TABLE 1. RECOMMENDED VEGETATION SPECIES

Scientific Name	Common Name
Sagittaria latifolia	Duck potato, arrowhead
Sagittaria lancifolia	Arrowhead
Nuphar polysepalum	Spatterdock
Pontederia lancifolia	Pickerelweed (narrowleaf)
Pontederia latifolia	Pickerelweed (broadleaf)
Scirpus robustus	Salt marsh bulrush

Certain herbaceous species should be avoided because they do not provide good habitat for mosquito predators. Also, they may grow in such dense thickets that the vegetation blocks mosquitofish from reaching the inner portions of vegetation zones. Floating cattail mats, for example, have particularly high mosquito counts. These mats may help protect mosquito larvae from predatory fish.

TABLE 2. UNDESIRABLE PLANT SPECIES FOR MOSQUITO CONTROL

Scientific Name	Common Name
Typha spp.	Cattail
Phragmites spp.	Common reed

SUMMARY

Research findings vary as to what percentage of stormwater impoundments currently provide good mosquito habitat. But there is no doubt about this: Where there is standing water, as in most stormwater facilities, there is a definite risk of mosquito presence. Stormwater BMP designers and managers have many useful tools to limit mosquitoes, including the introduction of mosquito predators, careful placement of the facilities, incorporation of design features preferred by mosquito predators, and proper vegetation selection and control.

RECOMMENDED READING

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