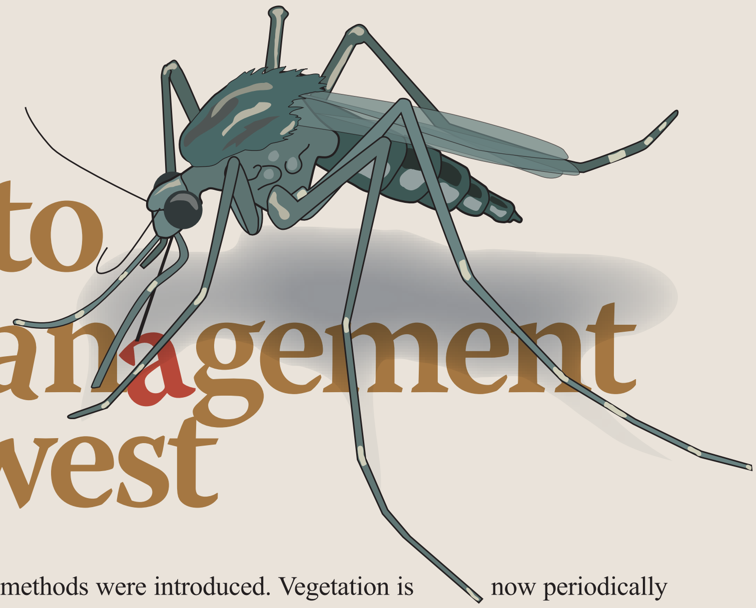
Approaches to Mosquito Management in the Southwest



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When we create wetlands in the Southwest, we simultaneously create habitat ideal for generating mosquitoes from April through at least October, as evidenced by data from Sweetwater Wetlands in Tucson. Mosquitoes are more than a nuisance: they can spread viruses that threaten humans and other animals, such as West Nile or western equine encephalitis. Over 50 species of mosquitoes exist in Arizona, each with unique characteristics. Some lay eggs in large open bodies of water; others prefer small potholes or cattle troughs that fill after a monsoon flood; still others are urban and prefer human-made, small containers. But only a few pose a major threat to us. Of those, only a subset is found in wetlands.

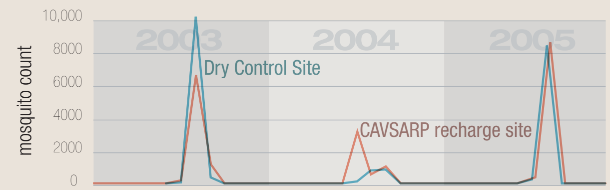
The two species of major concern at Sweetwater Wetlands are *Culex quinquefasciatus* and *Culex tarsalis*. These larvae thrive on decaying material in quiescent water while the surrounding vegetation provides shade, reduced temperature, and increased humidity for the adults, as well as habitat for the mosquitoes' prey. However, the mere presence of a wetland does not have to mean that large numbers of these mosquitoes will be generated. The overall design of the wetland and interventions such as habitat change and application of larvicide and adulticide can help control mosquitoes.

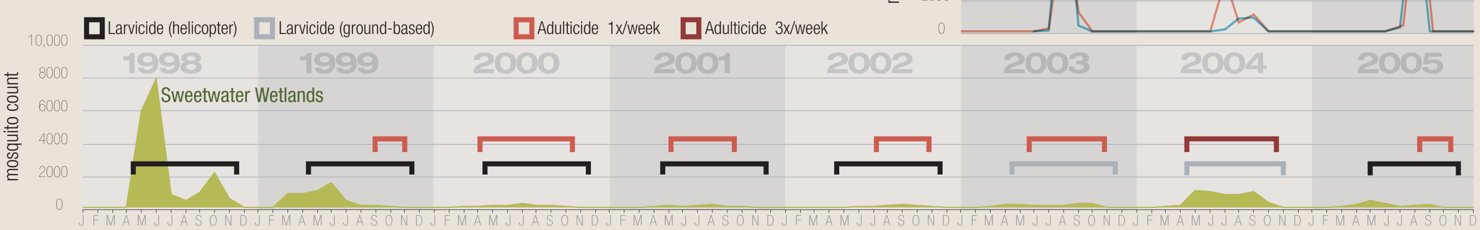
Sweetwater Wetlands, operated by Tucson Water, illustrates both the development of a mosquito problem and its subsequent management. It is a surface-flow, wastewater treatment-constructed wetland. It has both open-water deep zones and shallow zones planted with bulrush and cattail. Within three years of starting operations, it experienced a 100-fold increase in mosquitoes (Karpiscak et al., 2004). Weekly monitoring was implemented in 1998 (see chart below) and several abatement methods were introduced. Vegetation is now periodically burned when it is so overgrown that habitat diversity is jeopardized or when applied larvicide might not reach the water surface. Settling ponds were recently dredged to improve flow rates. Larviciding is used regularly throughout the mosquito season and adulticides are used when adult mosquitoes exceed threshold values.

Larvicides Are Bacteria

The most environmentally benign and mosquito-specific larvicides are two species of bacteria, *Bacillus thuringiensis israelensis* (Bti) and *Bacillus sphaericus* (Bs). When eaten by mosquito larvae, the bacteria release toxins that kill the larvae within a day or two. The bacteria do not typically survive long and are present for only a short time near the surface of the water where the larvae feed, so regular applications of the biological larvicide are needed. To help reduce the risk of developing resistance, larvicide products are rotated regularly. Weekly larviciding with the bacterium Bti three weeks per month and Bs on the fourth week per month was initiated at Sweetwater Wetlands in July 1998.

The larvicide application method seems to have a considerable impact on its efficacy at Sweetwater. A remote-controlled helicopter was used from July 1998 through November 2002 to distribute a dry preparation of larvicide across the wetland, enabling a relatively even distribution. During 2003 and 2004, the larvicide was distributed via sprayer from either a land-based or amphibious vehicle, and mosquito numbers rose. Tucson Water consequently contracted for use of the helicopter again,





Mosquito counts at Sweetwater Wetlands and the CAVSARP recharge site, 1998-2005; and a dry control site, 2003-2005. Data from Tucson Water.

beginning in May 2005, and mosquito numbers subsequently decreased.

Adulticides Effectiveness Unclear

The efficacy of adulticide spraying has not been proved. Tucson Water uses a two percent solution of Anvil, which is two percent Sumithrin (a synthetic pyrethroid) and two percent piperonyl butoxide. One downside of pyrethroids is that they are not highly specific for mosquitoes and so can also reduce mosquito predator levels; the two percent formula was used since it showed no significant effect on predator populations. Anvil was used extensively in 2004. Despite spraying once a week from March 29 to May 10, twice a week until June 20, then three times a week until mid-September, mosquito counts in 2004 remained considerably higher than the threshold of 100 mosquitoes per trap. In contrast, in 2005, Anvil was not used until August and then only once a week until the end of September when it was increased to twice a week after a mosquito pool tested positive for West Nile virus. Based solely on correlation, there is no evidence that spraying with two percent Anvil was effective at Sweetwater. Increasing to a ten percent solution might have been more effective, or, it might have been less effective since more mosquito predators would have been at risk.

Recharge Site Data

Tucson Water operates several recharge basins that have been occasionally faulted for generating vast numbers of mosquitoes. To test this possibility, Tucson Water compared mosquito population data from a full-scale recharge operation to a dry control site three miles to the south. Data from monthly mosquito counts at the Central Avra Valley Storage and Recovery Project (CAVSARP) recharge site and the control site were similar (see chart, opposite page), strongly suggesting that the recharge basins are not the source of mosquito breeding. Natural sheet-flow flooding appears to be the real culprit, since peak mosquito counts at both sites occurred during the monsoon season, even though CAVSARP operates year-round and temperatures are conducive to mosquito generation in more than the monsoon months. It is likely that during the monsoon season, many potholes and small dammed areas (natural or human-made) provide habitat for mosquitoes near both the active and inactive recharge sites (SWCA, 1998). In comparison, CAVSARP recharge basins are relatively unattractive for mosquito production because the Central Arizona Project source water is relatively low in organic material, vegetation is absent from the basins, and the water infiltrates relatively quickly, minimizing stagnant conditions.

Could Fish Stop the Itch?

One control method currently being investigated is the use of endangered native fish that feed on mosquitoes. Because the fish are endangered, they cannot be readily taken from one area and introduced into another, particularly if there would be risk that they might not survive in the new area. However, Safe Harbor Agreements may be negotiated that permit the use of endangered species without incurring as much legal liability. A few agencies have negotiated such

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How Do Larvicides Work?

Biological larvicides such as *Bacillus thuringiensis israelensis* and *Bacillus sphaericus* contain protoxin protein crystals that dissolve at the pH of the Culex mosquito's midgut. As the protoxins dissolve, smaller proteins (the actual toxins) are released and bind to receptors in the gut wall. The digestive system is paralyzed, pores develop in the gut walls, and additional toxins pass into the body cavity. The mosquito larvae die within one to two days. The specificity is excellent because particular gut conditions must be present for the toxin to become active and the toxin must bind to a particular receptor.

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agreements to provide habitats for some species of endangered native fish.

Another method, used in many mosquito-control districts in the country, is to introduce into the wetland a non-native fish, usually a species of *Gambusia* (more commonly called mosquitofish). *Gambusia* feed on mosquito larvae; however, they also have a tendency to feed on smaller fish, including some of Arizona's endangered native fish! Use of *Gambusia* therefore has not been encouraged. In an interesting twist, without Tucson Water's knowledge, someone recently stocked the gazebo pond at Sweetwater with *Gambusia*.

Be Vigilant!

In the Southwest, when the potential for standing water is high, we must be prepared to monitor for mosquitoes and act when appropriate. Vegetation grows, debris accumulates, water flows change. It may take a few years, but sooner or later, mosquito problems will emerge in any wetland or even in recharge basins if good maintenance is not practiced. In Southern California, one constructed wetland had the distinction of being the primary source of mosquitoes capable of vectoring western equine encephalitis for an area of approximately 23 km^2 (Walton, 2002) until its structure was changed. Vigilance is important.

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Wetlands also can be constructed in modules as the landfill is built out.

Other Factors: BOD, Ammonia, and Climate

Atmospheric exposure and the relatively long hydraulic retention times of the wetlands options result in very effective removal of the volatile priority pollutants. If the leachate BOD is consistently above 500 milligrams per liter (mg/L), then the use of a preliminary anaerobic pond or a VF wetland cell should be considered.

For landfill leachates with high ammonia content on the order of 300 mg/L or more, VF wetlands are usually required because they facilitate transfer of oxygen into the wetlands. These wetlands can be combined in series or with recirculation to treat high ammonia concentrations because they can transfer oxygen from the atmosphere into the sand where nitrification can occur. Intermittent dosing of VF wetlands (alternately wetting and drying) is similar in concept to using recirculating sand filters (Crites and Tchobanoglous, 1998).

Some advantages and benefits of the SSF wetland concept, such as preventing public contact with the wastewater, are not necessary at most landfill locations, so an FWS wetland may be a more cost-effective choice even if it requires more land. The exception may be in cold climates, where the thermal protection provided by SSF wetlands offers an operational advantage. The table on page 29 shows the performance of an FWS wetland treating landfill leachate in Mobile County, Alabama.

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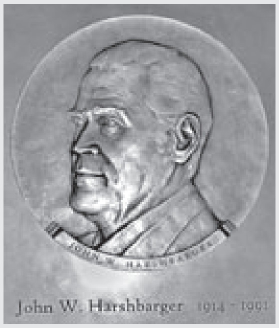
PEOPLE

Harshbarger Honored at UA



The late John W. Harshbarger was honored in November by the University of Arizona's Department of Hydrology and Water Resources. David R. Hargis, founder of Hargis + Associates consulting firm and a former student of Harshbarger, presented a bronze plaque at the ceremony, which was placed on Harshbarger's namesake building that houses the hydrology department.

Harshbarger joined the faculty of the geology department at the university in 1955, becoming head of that department six years later. He was instrumental in creating the hydrology department in 1966, and was its first chair.

Harshbarger was a geologist with the U.S. Geological Survey prior to arriving at the University of Arizona, and he built an active relationship between that agency and the new department. He also developed close ties with the Water Resources Research Center, which was established around the same time as the hydrology department.

Harshbarger's research and experience was diverse. He worked in the mining industry, exploring for uranium and vanadium. He was involved in the Manhattan Project. He initiated the first water resources survey of the entire Navajo Nation, and in 1966 he published *Arizona Water* (USGS Water Supply Paper 1648), a non-technical survey of Arizona's hydrology and water resources. Harshbarger eventually started his own consulting company in Tucson, where he worked the last two decades of his life, primarily in the area of groundwater development.

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