Summary of Report

Ecologically Sound Mosquito Management in Wetlands

Mosquitoes are a natural part of wetland ecology, and form a central component of the food web that supports a rich wildlife community.

Broad-scale chemical control harms wildlife and does not provide a long-term solution.

Public education is a key component of a successful integrated mosquito management program.

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Humans and mosquitoes have a long and contentious history. For centuries, people have tried to protect themselves, their pets, and their livestock from the irritation of nuisance biting and the effects of the disease organisms that some mosquito species can transmit. Early organized efforts to control mosquitoes were framed in terms of a war of annihilation, and implemented via a scorched-earth policy of drained and oiled wetlands and the use of highly toxic, broad-spectrum pesticides, the effects of which still linger in our landscape today.

Many currently used mosquito control agents are narrower spectrum and less toxic than those used in the past, but their use still has significant negative impacts on many aquatic invertebrates as well as the fish, birds, and amphibians that live and feed in wetlands.

Mosquito control is done using agents that kill the adult (adulticides) or immature (larvicides) form of the insect. The most commonly used adulticides are chemicals that have broad-spectrum toxicity and cause severe impacts to nontarget invertebrates, fish, amphibians, and birds. They have been implicated in declines in both wetland-associated and terrestrial wildlife, including endangered species that live near treated areas.

Mosquito larvicides include chemicals such as temephos (an organophosphate), which disrupts a larva's nervous system; growth regulators that disrupt larval development, such as methoprene and diflubenzuron; microbial agents such as *Bacillus thuringiensis* var. *israelensis* and *Bacillus sphaericus* that are toxic to mosquito larvae when ingested; and surface oils such as Golden Bear® (a petroleum-based mineral oil) that interfere with a larva's ability to breathe. Although these products are less toxic overall than broad-spectrum chemicals they can have nontarget impacts by killing organisms other than mosquitoes and disrupting food webs. Many fish, birds, and amphibians rely on aquatic flies which are negatively impacted through these products.

Mosquitoes are a central part of a vast food web that supports many other animals in and around wetlands, including tree swallows. Photograph: © Michel Bordeleau.

For instance, reduction of the aquatic insect food base can impact nest-site choices of female ducks as well as the food resources available to sustain ducklings and migrating waterfowl.

This fact sheet presents a summary of the scientific report *Ecologically Sound Mosquito Management in Wetlands. An Overview of Mosquito Control Practices, the Risks, Benefits, and Nontarget Impacts, and Recommendations on Effective Practices that Control Mosquitoes, Reduce Pesticide Use, and Protect Wetlands*. The report reviews over 400 scientific publications and lays out an approach to help land managers by providing solutions to mosquito issues that are both more effective and less toxic to the aquatic ecosystem.

There is no single mosquito management plan that can be equally effective at all sites; instead, our recommendations help land managers formulate a plan that is tailored to the individual needs and characteristics of the wetland while balancing the needs of the environment with those of the human community.

Impacts of Pesticides on Nontarget Animals

Modern mosquito control agents cause significant negative impacts to nontarget animals. These impacts may be due to direct toxicity, whether acute or via exposure to sublethal concentrations, or they may be indirect, occurring at the level of altered wetland community composition or by having an impact on the invertebrate food base for fish, birds, and other wildlife. Currently used mosquito control agents and their documented impacts include:

Organophosphates

Temephos (Abate®), malathion, and naled.

Organophosphates have broad-spectrum toxicity and negatively impact many aquatic organisms, including fish, dragonfly and damselfly nymphs, mayfly nymphs, water boatmen, microcrustacea, and non-biting midges. Drift from ultra-low volume sprays used against adult mosquitoes affects pollinators and butterflies, and low-flying aircraft used in spraying can disturb nesting birds.

Pyrethroids

Permethrin, resmethrin, d-phenothrin (sumithrin), and bifenthrin.

Pyrethroids are highly toxic to many aquatic organisms, including mayflies, stoneflies, caddisflies, and crustaceans. As with organophosphates, drift from ultra-low volume sprays used against adult mosquitoes affects pollinators and butterflies, and low-flying aircraft used to deliver sprays can disturb nesting birds.

Surface Oils and Films

Monomolecular films (Arosurf®, Agnique®), mineral-based oils (BVA2®), and petroleum oils (Golden Bear®).

Monomolecular oils and films create a barrier at the air – water interface that suffocates invertebrates that breathe atmospheric oxygen at the water's surface, especially aquatic bugs, beetles, and microcrustacea. These invertebrates are important predators of mosquito larvae, and their death reduces the level of mosquito control by natural enemies. Oils also can reduce hatching success of bird eggs and impair thermoregulation and foraging in ducklings.

Insect Growth Regulators

Juvenile hormone mimics (methoprene [Altosid®]) and chitin synthesis inhibitors (diflubenzuron [Dimilin®]).

Insect growth regulators are broadly toxic to insects and other invertebrates, especially crustaceans. Chronic effects of methoprene growth regulators include developmental disorders, physical defects, and reproductive anomalies in dragonfly nymphs, mayflies, beetles, crustaceans, and nonbiting midges. Methoprene may be linked to abnormalities that occur during in metamorphosis in amphibians.

Biological Controls: Microbial

Bacillus thuringiensis var. *israelensis* (Vectobac®, Aquabac®, Bactimos®, Summit®, Teknar®), *Bacillus sphaericus* (Vectolex®), and *Saccharopolyspora spinosa* (Spinosad; NATULAR®).

While some of these microbial controls are specific only to mosquito larvae, Bti is toxic to related flies such as non-biting midges, which comprise a large proportion of the animal biomass in wetlands and are an important food resource for aquatic invertebrates, fish, amphibians, bats, waterfowl, wading birds, and some passerine birds.

Biological Controls: Larvivorous Fish
Gambusia (mosquitofish).

Widespread introduction of this so-called "mosquitofish" into habitats where they are nonnative has had devastating effects on native fish and amphibians. Their voracious generalist feeding habit can reduce abundance of natural enemies of mosquitoes in the habitat and lead to increased mosquito numbers.

Despite the battery of mosquito control agents used to treat wetlands, stagnant water in bird baths, planter trays, and unused fountains is a major source of mosquitoes. Public education campaigns that focus on removing these breeding sites reduces biting significantly. Photograph by Matthew Shepherd/The Xerces Society.

Effective Mosquito Control that Minimizes Pesticide Use

The variety of aquatic habitats and mosquito species means there is no single magic bullet for mosquito control. Broad-scale chemical control harms wildlife and does not provide a long-term solution. Ecologically sound mosquito management requires a mixture of techniques adapted for different geographic regions, habitats, and communities, as well as frequent and effective communication between land managers, mosquito control agencies, and the public. Mosquito management should be tailored to each wetland. The following strategies will help in developing an holistic program.

Public Education
Many wetlands produce few or no mosquitoes, but backyard elements such as stagnant bird baths, clogged gutters, unmaintained ponds, and neglected pet dishes are fertile mosquito breeding grounds. Public education campaigns and community involvement focused on individual actions to remove these breeding sites are powerful tools in effective mosquito and disease control.

Interagency Cooperation
Federal, state, county, or city agencies can have conflicting wetland management goals. An interdisciplinary approach may require recognizing that the goal of a natural resource agency to maintain biodiversity is not in accord with the goal of a mosquito control agency to remove nuisance-biting mosquitoes, and both must work together to achieve mosquito management that provides control when needed with the least impact on the habitat and associated wildlife.

GIS-Based Surveillance
Factors that strongly affect mosquito development such as water, vegetation, and surrounding land use can be identified from available remotely sensed data and used to develop locally or regionally targeted control plans for different mosquito species. GIS surveillance is an effective tool that provides more comprehensive mapping than is possible on the ground, especially with limited staff and resources, and can enable identification and targeted

treatment of "hotspots" where mosquito production is a true problem.

Site-Specific Knowledge

People often assume that all wetlands produce nuisance or disease-carrying mosquitoes, but healthy wetlands with a diverse community of aquatic invertebrates, fish, amphibians, and birds that prey on mosquito larvae often produce few to no mosquitoes. Regular monitoring is critical to determine whether mosquitoes are emerging from a site and if so, whether the species prefer to feed on humans, present a nuisance-biting issue as opposed to a public health risk, and if they have the flight capability to disperse from the site into residential areas. Detailed knowledge of site topography, hydrology, precipitation, and vegetation can identify microhabitats producing the greatest number of mosquitoes that can be targeted for spot-control when needed, reducing mosquito abundance while leaving a majority of the habitat untreated.

Conservation of Natural Enemies

Invertebrates that prey on mosquito larvae include dragonflies and damselflies, beetles, true bugs, predatory flatworms, and crustaceans such as tadpole shrimp and copepods. These predators occur naturally in wetlands, and many can rapidly colonize newly flooded sites. Spiders, bats, amphibians, fish, and birds also consume mosquitoes. These animals are all generalist predators that do not target mosquitoes specifically, but their presence in a wetland can reduce and even completely control mosquito populations. Mosquito management practices that conserve or enhance populations of natural enemies can reduce mosquito numbers while protecting the food chain, sustaining an intact and diverse biotic community, and conserving rare or endemic species in the habitat.

Vegetation Management

Constructed wetlands, such as those used in urban stormwater management, can be designed and constructed with features that significantly reduce the ability of the site to produce mosquitoes. Constructed wetlands that are steep-sided, have less than 20% of the basin covered by vegetation, and provide for different levels of water and flow rates, including deeper pools where natural enemies can establish, are linked to decreased mosquito production. These sites rarely need additional mosquito control. Vegetation management to improve habitat for waterfowl can also be tailored to sustain waterfowl while reducing mosquito numbers and increasing the abundance of other invertebrates eaten by waterfowl.

Bait Traps

Attractant-based traps for "attracticide" (lure and kill) mosquito control are still highly experimental, and their efficacy has varied greatly depending on location, habitat, and mosquito species. However, bait traps may have some potential to reduce mosquito abundance, especially in areas where one species dominates the population or where adult mosquitoes do not disperse far from the larval habitat.

To download the full report go to www.xerces.org.