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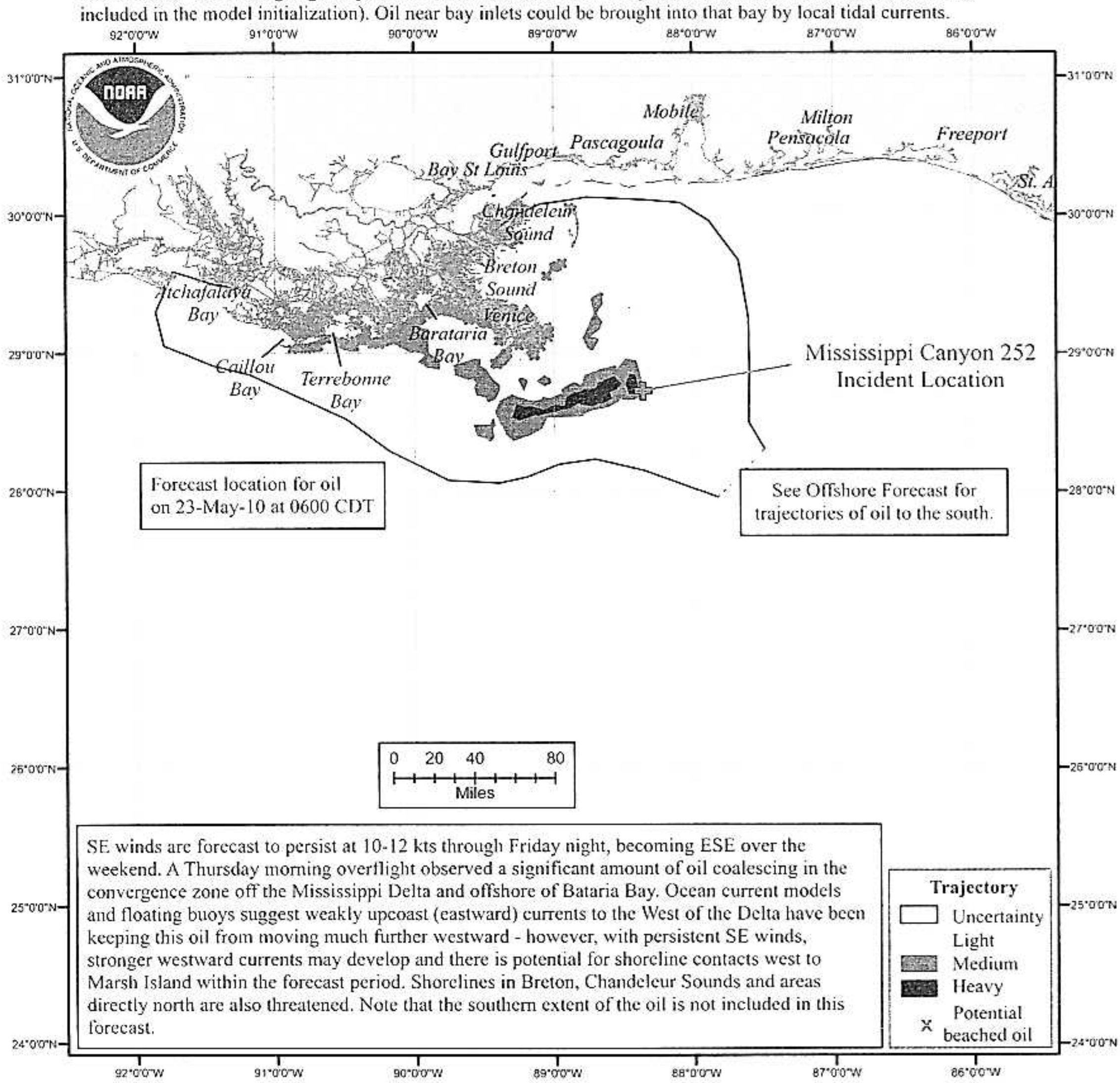
Surface Oil Forecast Mississippi Canyon 252

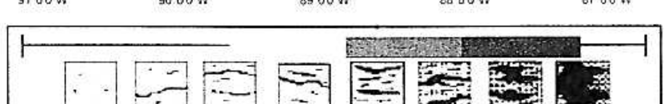
NOAA/NOS/OR&R

Estimate for: 0600 CDT, Sunday, 5/23/10

Date Prepared: 1300 CDT, Thursday, 5/20/10

This forecast is based on the NWS spot forecast from Thursday, May 20 AM. Currents were obtained from several models (NOAA Gulf of Mexico, West Florida Shelf/USF, Texas A&M/TGLO, NAVO/NRL) and HFR measurements. The model was initialized from Thursday morning satellite imagery analysis (NOAA/NESDIS) and overflight observations. The leading edge may contain tarballs that are not readily observable from the imagery (hence not included in the model initialization). Oil near bay inlets could be brought into that bay by local tidal currents.





Next Forecast: May 21st AM

this scale bar shows the meaning of the distribution terms at the current time

Mosquito Control and Wetlands

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INTRODUCTION

Wetlands are known to provide important ecosystem services such as wildlife habitat, floodwater control, water quality improvement, and carbon sequestration. Wetlands are also natural sources of mosquitoes and wetlands managers, regulators, and scientists must recognize and deal openly with that fact and also with the fact that mosquito control may sometimes conflict with management for other important goals such as maintaining biodiversity (Willott 2004). Organized mosquito control programs can be a source of professional guidance and other assistance to parties who are creating new wetlands, restoring degraded wetlands, or acting as stewards and managers of natural wetlands, but where mosquito control programs do not exist, or are only weakly supported, the mosquito problems are particularly challenging to manage.

If we are to meet the mandate of "no net loss" of wetlands, wetland professionals must address the public's perception of the role of wetlands in mosquito production and in vector-borne disease transmission with an integrated approach that includes public education and outreach, soliciting public input from a wide range of stakeholders, and encouraging research on management techniques that achieve mosquito reduction goals while simultaneously maximizing the ecosystem services provided by wetlands.

The goals of this paper are to provide an overview of the context for present-day mosquito control and to review some options available to wetland managers to reduce mosquito production in wetlands. We do not endorse the use of any specific management technique

identified in this paper. It is our goal to encourage research on management techniques and policies that address mosquito problems and also maintain robust wetland ecosystem services.

MOSQUITO ECOLOGY

Mosquito-transmitted diseases of primary concern in North America are West Nile Virus, Eastern Equine Encephalitis, Western Equine Encephalitis, and La Crosse Encephalitis. The biology and ecology of mosquito species is highly relevant to the informed management of wetlands for such mosquito-transmitted diseases. For example, the primary habitat for specific species of *Culex*, the main vector for West Nile Virus, may be storm water systems in US urban areas but over-irrigated agricultural fields in rural areas of the western US.

The females of different mosquito species can be highly selective of oviposition sites according to environmental factors and hydrologic conditions. However, mosquitoes can be classified into two broad groups based on their oviposition behavior (Knight et al. 2003), namely the floodwater-ephemeral water habitat mosquitoes or the permanent-semipermanent aquatic habitat mosquitoes. Floodwater mosquito eggs are deposited on moist substrate and do not hatch until subsequently inundated. They include mosquitoes in the genera *Aedes, Ochlerotatus,* and *Psorophora* that are primarily daytime or crepuscular feeding mosquitoes. These mosquitoes can be significant vectors for diseases (Monath 1988). Floodwater mosquitoes are prevalent in sites receiving agricultural runoff and along wetland edges. Adults do not overwinter, but eggs laid in soil or in artificial containers do.

Permanent or semipermanent aquatic habitat mosquitoes lay eggs singly (*Anopheles* spp.) or in large rafts (*Culex* spp.) of 100 eggs or more on the water surface. These eggs hatch within a few days without an external hatching stimulus.

RISK ASSESSMENT

Risk assessment is the first step in developing a mosquito control strategy. Managers, regulators and the public must recognize that the mere presence of a wetland does not indicate that the site is an important source of mosquitoes or mosquito-transmitted disease. It is important to fully understand the extent to which responses that negatively affect wetland ecosystems will actually contribute to solving a given mosquito problem. Persons assessing risks should determine the answers to the following questions: (1) How do local and regional wetlands fit into the overall mosquito problem? (2) When does a mosquito problem become severe enough to warrant interventions that impact wetlands? (3) How will potential control strategies be tailored to address the problem while minimizing wetland impacts? (4) Is there a phased or step-wise approach that can limit response to only that required to control specific situations? (5) Have alternatives been considered that minimize the loss of valued wetland services or avoid potentially converting wetlands from one type to another?

Mosquito surveillance is often carried out by professional mosquito control programs or county and state health departments. The objectives of such programs should be to establish both baseline and current data bases of mosquito diversity and abundance, map breeding and/or harboring habitats, estimate relative changes in population sizes, assess disease risk, and determine nuisance levels.

Management plans should incorporate accepted principles of integrated pest management (IPM). They should include a hierarchical scale of increasing risk levels to human or wildlife health, quality of life, and economic activity based on local or regional disease activity, and species-specific or overall mosquito population numbers. These threats vary temporally and spatially, so they must be determined locally. The plan should then include appropriate actions to take for each level.

Thresholds for treatment actions may be species specific and reflect the potential significance of a particular species or group of species in a particular health threat. For example, mosquito species known to be important in the transmission of a disease in a particular geographic area may have a lower action threshold than species with lesser transmission roles. It is also important to distinguish disease-related threats from public nuisance in considering control actions. We encourage plans that weigh negative impacts of actions on wetland ecosystems against the negative impacts of mosquitoes on humans and wildlife.

MOSQUITO CONTROL STRATEGIES

For the purposes of this paper, *lightly managed* wetlands are those that are intended to be natural or require minimal management. *Heavily managed* wetlands are those that require intensive human management, generally including active water-level manipulation.

In some situations, a compromise between achieving all the desired wetland values and functions versus near-total suppression of mosquito production may be necessary (Dale and Knight 2008). For constructed or restored wetlands, design features and management practices based on basin configurations, water-level management, mosquito predators, and vegetation management can help reduce mosquito production (Knight et al. 2003, Mayhew et al. 2004). If such steps fail to achieve satisfactory mosquito control, then additional biological or chemical controls might be needed, and may become the responsibility of mosquito control professionals. The extra expense incurred for contending with mosquito production from created or restored wetlands can be viewed as another cost of having or creating wetlands, an expense that may need to be planned for as an element of responsible wetland stewardship.

The potential change in mosquito production as a result of restoring wetlands can be minimal and increases in mosquito production can be minimized if environmentally sound mosquito, source reduction measures are incorporated into the project's design, construction, management, and maintenance. This will be most important where wetland restoration projects involve relatively large acreages in close proximity to human habitations.

Techniques Suitable For Natural and Lightly Managed Wetlands

Passive approaches

Passive techniques include warning the public about presence of mosquitoes and restricting access to the wetland rather than implementing active mosquito control. Such actions should always be based on surveillance data. Wetland managers must avoid creating a perception that wetlands are inherently mosquito "factories." Rather, it should be stressed that while mosquitoes, like other aquatic insects, are produced in wetlands, in most cases their numbers do not reach public health concern or even nuisance levels. A passive strategy may not be acceptable in cases where there is a public health threat or the wetland produces more mosquitoes than the local human population can tolerate.

Biological control and mosquitocides

If passive approaches are not sufficient, mosquito control agencies will generally implement an IPM protocol that includes the introduction of mosquito predators and the judicious use of insecticides. Biological control is typically focused against the aquatic stages of the mosquito life cycle. At present, small, larvivorous fish such as mosquitofish (*Gambusia* spp.) are the only biological control agents for larval mosquitoes that are actively being used in wetlands (Swanson et al. 1996, Walton 2007), but there are other possible control agents such as dragonfly larvae and predaceous copepods. There is no credible scientific evidence that any avian or bat species can effectively control adult mosquitoes, but the efficacy of alternative species continues to be evaluated. One important consideration is the risks to native ecosystems of introducing non-native species (Rupp 1996, Gratz et al. 1996, Pyke 2008). There are settings where this approach can be ecologically sound, practical, and cost-effective, and avoid or reduce the need for insecticide treatments (Sakolsky-Hoopes and Doane 1998, Kent and Sakolsky-Hoopes 1999, Meredith and Lesser 2007). Questions that remain to be addressed include: (1) Under what environmental conditions are the fish effective as biological control agents? (2) Do the reductions in mosquito populations significantly reduce disease transmission to humans? and (3) Do mosquitoes show compensatory responses to the reduced effects of larval stage density dependence?

When passive and biological control methods are insufficient, use of larvicides is preferred because control efforts are focused on the source of the problem and the area treated is typically much smaller than with adulticides that are applied after adult mosquitoes have emerged and dispersed widely. The most commonly used larvicides are: (1) Monomolecular films (MMFs) that are used to treat container-type habitats or other relatively small wetland

Figure 6. A snowy egret feeds along a tidal creek in Groton, CT. Tidal creeks are home to resident fishes like mummichogs (Fundulus heterolclitus) and sheephead minnows (Cyprinodon variegatus) which are the principal biological control agents (on the east coast) of mosquito larvae as used in open marsh water management (omwm).

areas, (2) Bacteria such as *Bacillus thuringiensis* var. *israelensis* (de Barjac) (Bti) and *B. sphaericus* (Neide) that produce mosquito toxins but present minimal risks to humans and other non-target organisms, (3) Insect growth regulators such as methoprene that prevent immature mosquitoes from molting into adults and also have very little (if any) effect on non-target organisms (Balcer et al. 1999). (4) The organophosphate temephos is a chemical that for some mosquito control programs provides the only affordable, practical, and effective larvicide for treating large geographic areas.

If larvicides cannot be used or prove ineffective, it might be necessary to resort to the use of adulticides. This method usually involves more widespread applications of the insecticides, often directly over or within where people live, work, or recreate. The most commonly used adulticides include organophosphates (e.g., malathion, naled) and synthetic pyrethroids (e.g., permethrin, resmethrin, sumithrin). The U.S. Environmental Protection Agency (EPA) registers mosquitocides (for larvae or adults) that it determines do not pose unreasonable risks to human health, wildlife, or the environment.

Water management

The flow of water through a wetland and its related volumetric turnover rate influence mosquito production, but flow rates detrimental to immature mosquito survival are too high to be practical for effective mosquito control. Adequate water turnover rates however, can reduce mosquito production by helping to eliminate the accumulation of stagnant, organically-rich waters that attract certain standing-water mosquitoes such as *Culex* spp. and by enhancing the survival of aquatic predators of mosquito larvae. In many Midwestern wetlands, such as fens, sedge meadows, and dolomite prairies, groundwater contributions from seeps, springs, and upwelling can provide this slow flushing, as well as maintain colder water temperatures not suitable for many mosquito species. Water management is also used as an indirect means to manipulate the presence and biomass of vegetation (see below).

Techniques Suitable for Heavily Managed Wetlands

The discussion below assumes that mosquito control, as opposed to maintaining or enhancing wetland functions and services, is the primary goal of wetland management.

Basin design and topographic configurations

Wetlands should generally not be subjected to changes in topography for the sole purpose of mosquito control, with the possible exception of restoring predator balance in a degraded wetland. However, when mosquito reduction is the primary goal, there are topographic design considerations that may be applied to minimize mosquito production and the need to apply pesticides.

Creating deep water zones (>1.5m) often provides habitat for important predators of mosquitoes such as larvivorous fishes, predaceous aquatic insects, and salamander larvae that often considerably reduce mosquito production. Wetlands that have gently sloping margins or edges (e.g., a vertical:horizontal slope of <1:10) tend to develop dense emergent vegetation in shallow areas. The physical structure of emergent vegetation provides several important wetland functions (Mitsch and Gosselink 2000, Kadlec and Wallace 2008) and is frequently a goal in wetland mitigation or restoration. However, dense vegetation can also create refugia from predators for mosquito larvae. Steeper side slopes (e.g., >1:4) are less prone to develop dense vegetative cover but these slopes may be more susceptible to soil erosion. Regardless of the slope, if the intent is primarily to control mosquito production,

Figure 7. Beach grass along a flooded saltmarsh in Old Saybrook, CT. Saltmarshes can be prolific breeding sites of several species of mosquitoes.

the sides should taper downward from shallow edges towards a deeper central water body. This prevents isolated pockets of standing water along a wetland's margins during drawdown or droughts and after rainfall events that do not completely fill the wetland basin (Knight et al. 2003).

Water Management

Design features and operations that move water through wetlands are critical to managing mosquitoes but before selecting this management technique, one must examine the type and functions of the wetland in question. Numerous wetland types are not suitable candidates for significant water-level management.

In addition to the goal maintaining a permanent pool of water (see below), the margins of wetlands should not undergo extensive wet-dry-wet cycles that can lead to production of floodwater mosquitoes from peripheral micro-habitats that lack mosquito predators. When a wetland dries out, many aquatic predators of mosquito larvae perish, while floodwater mosquitoes survive as eggs that remain viable in moist mud or desiccated bottoms and then hatch soon after water is again present. When a wetland has permanent water cover, along with open channels or paths through thick vegetation for aquatic predators of mosquito-larvae to move around, the production of standing-water mosquitoes (e.g., *Culex* spp.) is lessened. Deeper water also reduces production of mosquito larvae that attach to the roots of emergent plants (e.g., *Coquilletidia perturbans*).

Vegetation management

The primary goal of vegetation management is to create open water areas that are unfavorable for immature mosquito development and for adult mosquito resting. Open water areas enhance the negative effects of wind on mosquito activity, deter oviposition, reduce immature mosquito survival by increasing predation and drowning by waves, and lower the accumulation of organic debris in a wetland system. Management may involve selective plant removal, controlled burning, or minimal applications of herbicide. Limited mowing, disking, and grazing are also used to alter plant species composition and abundance in order to enhance use by certain species of wildlife (Payne 1992, Kwasny et al. 2004). Design features such as raised planting beds and deep water zones that limit the proliferation of emergent macrophytes (Thullen et al. 2002) provide more effective mosquito control than does repeated vegetation removal.

Vegetation suppression is generally not favorable for important wetland functions and services such as wildlife habitat or water quality improvement. Many wetland functions emerge directly from the diversity and primary productivity of the plant community. In addition, disturbances such as mowing, disking, and grazing may create opportunities for invasive species colonization. Compromise in management strategies may be required, depending on the desired balance between maintaining wetland functions and reducing mosquito production.

Source reduction

Source reduction refers to non-chemical techniques that are designed to limit mosquito production at oviposition sites or larval-rearing sites. Because source reduction typically involves habitat modification, the strategy is generally used as a final recourse for reducing mosquito production and the need for insecticide use. The range of impacts of source reduction has not been fully assessed, but there are tradeoffs between the benefits from mosquito control and reduced insecticide use, and the adverse effects of habitat alteration on wetland ecosystem functions. For this reason, we consider source reduction appropriate primarily for wetland ecosystems that are heavily managed.

The type and extent of source reduction that is possible in a given wetland depends upon how much water-management capability exists for managing water flows and wetland water levels. More sophisticated source reduction can be achieved when capabilities for fine-tuned dynamic management of water flows and water levels are available. For many natural wetlands, especially groundwater-fed wetlands with saturated soils this technique is not appropriate or even possible without destroying the wetland or converting it to a completely different wetland type.

Source reduction in wetlands customarily encompasses three broad categories of control measures: (1) basin/topography design configurations, (2) water-level management, and (3) vegetation management. These measures are most applicable in wetlands that were constructed or developed for specific purposes, often focusing on a single wetland function, but usually providing other wetland functions.

Analyses, recommendations, or BMPs that address source reduction in wetlands have been published for New Jersey (Shisler and Charette 1986, New Jersey Department of Environmental Protection (NJDEP) 2004), Maryland (Dorothy and Staker 1990, Bradley and Kutz 2005), Florida (O'Meara 1997, University of Florida 1998), California (Walton 2003, Kwasny et al. 2004, Metzger 2004), and coastal wetlands (Brockmeyer et al. 1997). The EPA recently released a new nationwide set of BMPs for stormwater retention ponds and their associated wetlands (EPA 2009).

"Open marsh water management" (OMWM) is a selective ponding-and-ditching technique designed to reduce mosquito oviposition sites and encourage predation of mosquito larvae by native fishes in tidal wetlands (Meredith et al. 1985). Although the goal is to minimize changes in wetland structure and function, OMWM can effectively alter the functional type of a wetland. For this reason and others, this is not a technique applicable to all locations or one that would be accepted in all locales. "Runnelling" is a modification of OMWM (Hulsman et al. 1989) that may be used in tidal marshes with acid sulphate soils (Wolfe 1996, Dale 2005).

It should be noted that the old parallel-grid-ditching method of source reduction for salt marsh mosquito control, which involved excavation of open tidal ditches geometrically placed over vast acreages, was generally ineffective in controlling mosquitoes, had significant negative impacts on coastal marshes, including substrate disturbances that led to the introduction of invasive species (e.g., *Phragmites*), drying of marsh surfaces that led to increased oxidation, and loss of marsh substrate, and changes in plant communities (e.g., establishment of shrubs) and wildlife habitat values The technique of OMWM, when properly employed, avoids almost all of these past adverse impacts. In fact, in previously parallel-grid-ditched marshes, the installation of OMWM systems is often viewed as a habitat-restoration technique by restoring standing water to marsh surfaces that have been dewatered by the parallel-grid-ditches (Meredith et al. 1985).

CONCLUSION

Wetlands are complex systems that provide many crucial environmental and socio-economic functions, services, and products. As society is confronted with new and emerging mosquito-borne diseases, the need to simultaneously protect human health and wetland functions will only increase. If society wishes to sustain the mandate of "no net loss" of wetlands through preservation, creation, or restoration of these valuable ecosystems, then wetland professionals must address the public perception about mosquito production and vector-borne diseases in wetlands with an integrated approach that includes providing public education and outreach while soliciting public input. Additionally, society must confront development that significantly degrades wetlands, and juxtaposes humans with unstable biological systems.

Wetland professionals, regulatory agencies, public health organizations, mosquito control agencies, and private citizens should collaborate during the planning, design, implementation, management, and maintenance phases of wetland creation, restoration, or enhancement projects. One price of creating and restoring wetlands may be the need to monitor for mosquito production. Criteria for the long-term success of projects must include the minimization of mosquito production to the extent practicable, done in an environmentally-compatible manner consistent with the achievement of other objectives specified for a particular project (Willott 2004).

Mosquito species have evolved to exploit a wide variety of habitats. Because mosquitoes are a natural part of wetland ecosystems, permanent and total elimination of mosquitoes from wetlands is not a realistic or achievable goal. However, current scientific understanding supports the position that we can take environmentally-compatible measures to help minimize mosquito production from natural, created, or restored wetlands, and especially from many types of degraded wetlands. We advocate science-based use of system design concepts that encourage ecological diversity and natural mosquito predators in all wetland types, minimizing to the extent practicable the creation or perpetuation of site features that promote mosquito production in the first place.

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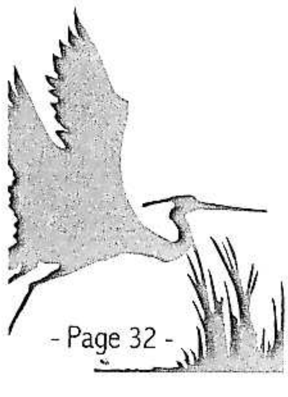

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