IDENTIFYING MOSQUITO LARVAE HABITAT CREATED BY CBNG DISCHARGE WATERS USING REMOTE SENSING[1]

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Abstract. Water disposal methods such as pond storage and in-channel releases that are associated with coalbed natural gas production (CBNG) have increased the amount of standing water in the Powder River Basin, Wyoming. These standing waters have been shown to be potential larval habitats for the *Culex tarsalis* mosquito, the primary vector of West Nile Virus (WNV) in Wyoming. This paper presents preliminary findings from an ongoing research effort focused on identifying environmental and anthropogenic risk factors for WNV associated with CBNG production. Field research suggests that retention pond design and water disposal techniques may serve as either mitigating or compounding factors for risk. Ninety percent of drainages receiving discharge waters tested positive for *C. tarsalis* while only 23% of reservoirs showed larvae presence. A GIS-based risk model based on field observations for CBNG production areas has been developed and tested in which the primary risk factors are *C. tarsalis* larval habitat and water disposal mechanisms. Preliminary findings using Landsat imagery show a sharp increase (75%) in potential *C. tarsalis* habitat resulting primarily from CBNG discharge waters. These estimates, based on large-scale remote sensing data, are a conservative estimator of WNV risk associated with the creation of mosquito habitat in active CBNG production in the Powder River Basin. High resolution imagery (Quickbird and SPOT) has been tested and found to identify habitat regions below the lower limit of detection with Landsat.

Additional Key Words: GIS, risk analysis, West Nile Virus, coalbed methane

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Introduction

The West Nile Virus (WNV) is a member of the Japanese encephalitis serocomplex (Hayes, 1989) that affects the central nervous system of vertebrates and causes a serious threat to public health. WNV has spread across the North American continent since it was first detected in 1999 (Enserink, 2002), and by 2004, total human deaths had reached 374 nationwide. The state of Wyoming was hit heavily in 2003 with 375 human cases including 9 deaths (CDC, 2004). Mosquitoes of the genus *Culex* are efficient vectors that transmit WNV (Hayes, 1989; Goddard et al., 2002), and in Wyoming, the primary vector has been identified as *Culex tarsalis* (Schmidtmann, unpublished data).

In addition to posing a clear threat to human health, WNV poses a threat to native wildlife species. For example, WNV appears to have caused a sharp decline of greater sage-grouse (*Centrocercus urophasianus*) in the North-central portion of Wyoming, specifically the Powder River Basin where survival was reduced by 25 % (Naugle et al., 2004). At a minimum, alterations to the landscape and subsequent threats to wildlife and people indicate that monitoring and controlling WNV is a critical and potentially long-term commitment requiring a temporal and spatial strategy.

The larval habitats of *C. tarsalis* are small standing water bodies with high organic matter that have a very small amount of disturbance either in the form of wave action or flow. In a natural environment, larval habitats of *C. tarsalis* are often associated with vegetation growing at pond edges (Reisen, 1993). Large water bodies (usually large than 4 hectares) that are exposed to wind and wave action, and running water such as a river or stream, are not suitable for larval development. In the Powder River Basin and other CBNG fields, human-made water storages, such as discharge water ponds constitute the most likely breeding and larval habitat.

CBNG is a naturally occurring gas contained within unexposed coal beds, and recent changes in the domestic market and technological advances have made it economically feasible to extract the gas. Critical to this study, CBNG is held in place by water, and in order to extract the gas the water must be removed and disposed of, either through re-injection or surface disposal. The amount of water produced in this manner is considerable. Rice et al. (2000) estimated that 1.28 million barrels (150,205 MCF) of water was produced each day from CBNG extraction in 2000. Since 1999 when it became economically feasible to tap natural gas in the Powder River Basin, over 24,000 CBNG wells have been drilled, and over 19,000 additional wells have been permitted but not yet made active (WOGCC, 2007).

In the study area of the Powder River Basin the dominant mechanism for disposal is via surface release, either into retention ponds or via effluent discharge into small ephemeral channels. These recent increases in ponded and slow moving waters are hypothesized to increase WNV risk because these waters may establish and serve as suitable habitat for larval *C. tarsalis*. The overall goal of this study is to build a functional GIS-based toolkit that utilizes remote sensing techniques and field research for WNV risk assessment resulting from CBNG production.

Preliminary Findings

Field Research

Potential *C. tarsalis* habitat was sampled July 25 - September 8, 2006 in Campbell and Johnson Counties, Wyoming. Through communication with private land owners, CBNG discharge ponds and drainages that had not been recently treated with *Bacillus Israeliensis*, a larvacide used in mosquito control, were targeted as sampling locations. Initial efforts were focused on sampling CBNG retention ponds. However, few mosquitoes were found at ponds due to low water levels, muddy shorelines, and wave action. Consequently, our focus shifted to low-gradient ephemeral drainages with CBNG discharge water. A total of 63 locations were sampled. At each location, a minimum of 5 and a maximum of 20 points were sampled depending on the abundance of available habitat. This summed to a total of 795 points sampled. At any location, no two points were closer than 10 m from each other. Three mosquito sampling 'dips' were taken at each point to maximize coverage. When mosquito larvae were detected at a point, at least three larvae were preserved for later identification. Qualitative information about aquatic and bank vegetation were recorded at each point. A digital picture was also captured at each point, as well as a sub-meter accuracy GPS position (Trimble ProXRS differential GPS with post-processing; average spatial error was 20 cm).

Mosquito larvae were found at 29 of the 63 locations (46%) and all but one of those positive locations had *C. tarsalis* larvae. This indicates that, at least during late summer, most mosquitoes in the region are potential West Nile Virus vectors. *C. tarsalis* larvae were much less common at reservoirs (23%) than in drainages (90%) (Table 1).

Table 1. Presence of *C. tarsalis* larvae according to CBNG water discharge technique.

	CBNG Reservoir Locations	CBNG Drainage Locations
C. tarsalis present	10 (23%)	18 (90%)
C. tarsalis absent	33 (77%)	2 (10%)
Total	43	20

Vegetation parameters suggest a correlation between recently flooded dryland grass species and *C. tarsalis* presence. Another important factor is sufficiently shallow (<12 cm) and stagnant water. In other words, if water is channelized and moving quickly through drainages, mosquito habitat is minimized. Two confounding variables were identified in our initial field seasons. First, it was impossible to conclusively track the deployment of mosquito control devices in discharge ponds and channels. Second, the absence of larvae in the field is not necessarily indicative of inadequate habitat, especially when similar sites are identified with abundant larvae.

Remote Sensing

The development of the remote sensing techniques for larval habitat identification used in this effort is detailed in Zou et al. (2006). These techniques were improved upon in this effort at classifying 30 m resolution Landsat data into vegetation and water bodies that could be used to identify suitable habitat. Emergent vegetation is a critical condition for the identification of suitable habitat, as is the presence of water. However, larger water bodies such as open discharge ponds are rendered unacceptable due to the fact that wind action and lower organic contents reduce the suitability for larval growth and maturation. A set of GIS rules were used to refine the selection of suitable sites, such that steep slopes and pre-existing large waterways were excluded. This is a conservative approach to estimating habitat since it restricts the identification to only small bodies of water with abundant vegetation and low slopes using relatively coarse data.

The use of Landsat imagery showed an overall increase in *C. tarsalis* habitat of 75% from 1999-2004 (Zou et al., 2006). An accuracy assessment using field data and high-resolution aerial photography showed that the classifier can identify likely habitat for ponds larger than 0.8 ha (2 acres) with generally satisfactory results (72.1%) with a lower detection limit of 0.4 ha (1 acre) that is due to the relatively coarse 30m resolution of the imagery (Zou et al., 2006).

To address the issue of temporal change and spatial scaling both conventional (Landsat 5 TM: 30 m multispectral) and high resolution data (Quickbird: 2.4 m multispectral and 0.5 m panchromatic; and SPOT: 12 m multispectral) were collected over the field sites for 2005 and 2006 seasons. These data were classified following the rules set forth by Zou et al. (2006) with suitable results found for the identification of larval habitat.

The contrast in use of Quickbird and Landsat imagery is detailed in Fig. 1. As expected when using high resolution imagery, small-scale features are more readily detectable. Channels and small impoundments larger than approximately 50 m^2 (0.005 ha, or 0.01 acres) can be identified, compared to a lower limit of 4 ha (10 acres) with Landsat. This range is more suitable for accurately resolving micro-habitats that form a high percentage of the *C. tarsalis* habitat in the study area. The trade-off in cost, data acquisition, and computational efficiency is noteworthy, of course, and from an operational standpoint the use of Landsat may still be preferred.

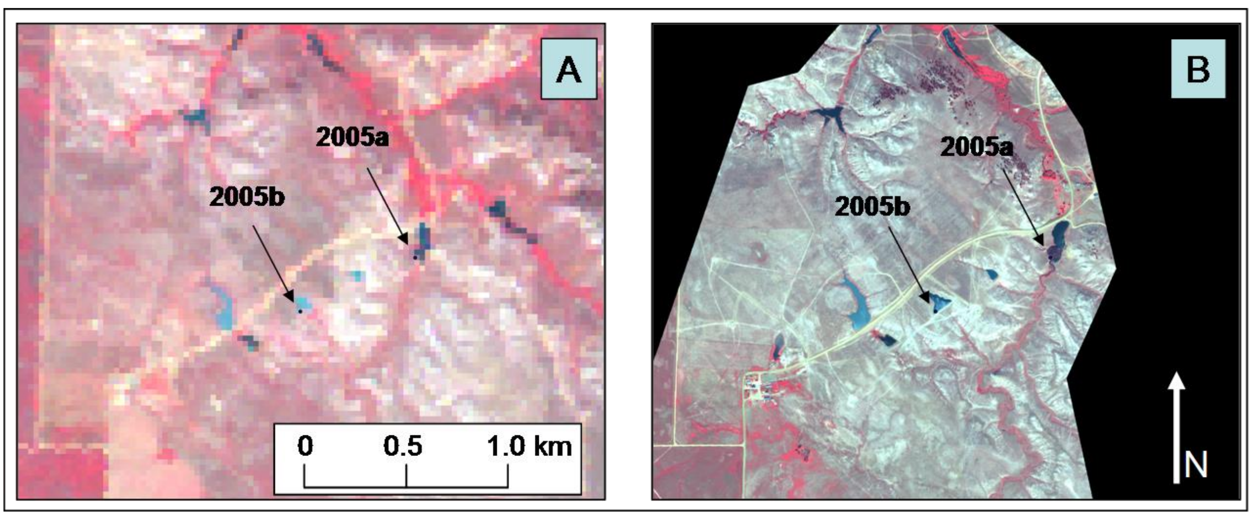

Figure 1. Comparison of false color composite remote sensing imagery covering a portion of the 2005 field research area. Figure 1a is Landsat imagery (30 m); Fig. 1b is Quickbird multispectral bands (2.4 m) with arrows in both panels indicating the same positive habitat sites detected in the field. Landsat imagery was able to detect the larger site (2005a) but unable to detect the smaller site (2005b) while Quickbird was able to detect both.

Summary

A GIS-based habitat classification model for *C. tarsalis* mosquito larvae has been built for the Powder River Basin, Wyoming, using Landsat remote sensing data and a rule-based spatial modeling system. This approach produces a conservative estimate of suitable habitat due to restrictions in minimum detection size and resolution. High resolution data sets have been tested and found to be superior in identifying suitable habitat that was missed using the Landsat data. A multi-year field campaign has served to refine the conditions for suitable habitat and assist in the definition of landscapes at risk for enhanced production of *C. tarsalis* mosquito that is currently being used to refine the GIS-based model. Co-produced waters associated with CBNG production in the Powder River Basin have increased *C. tarsalis* larvae habitat. This increase in suitable habitat is implicated in an increased risk to wildlife, livestock, and people to West Nile Virus. Effective management of co-produced waters can reduce larval habitat since field efforts have found that the greatest abundance of larvae are found in small drainages systems with abundant vegetation and slow moving waters, while relatively few larvae were identified in reservoirs or channelized streams.

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