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Mapping an invasive plant, *Phragmites australis*, in coastal wetlands using the EO-1 Hyperion hyperspectral sensor

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Abstract

Mapping tools are needed to document the location and extent of *Phragmites australis*, a tall grass that invades coastal marshes throughout North America, displacing native plant species and degrading wetland habitat. Mapping *Phragmites* is particularly challenging in the freshwater Great Lakes coastal wetlands due to dynamic lake levels and vegetation diversity. We tested the applicability of Hyperion hyperspectral satellite imagery for mapping *Phragmites* in wetlands of the west coast of Green Bay in Wisconsin, U.S.A. A reference spectrum created using Hyperion data from several pure *Phragmites* stands within the image was used with a Spectral Correlation Mapper (SCM) algorithm to create a raster map with values ranging from 0 to 1, where 0 represented the greatest similarity between the reference spectrum and the image spectrum and 1 the least similarity. The final two-class thematic classification predicted monodominant *Phragmites* covering 3.4% of the study area. Most of this was concentrated in long linear features parallel to the Green Bay shoreline, particularly in areas that had been under water only six years earlier when lake levels were 66 cm higher. An error matrix using spring 2005 field validation points ($n=129$) showed good overall accuracy—81.4%. The small size and linear arrangement of *Phragmites* stands was less than optimal relative to the sensor resolution, and Hyperion's 30 m resolution captured few if any pure pixels. Contemporary *Phragmites* maps prepared with Hyperion imagery would provide wetland managers with a tool that they currently lack, which could aid attempts to stem the spread of this invasive species.

Keywords: Phragmites; Remote sensing; Hyperspectral; Hyperion; Invasive species; Wetlands; Great Lakes; Green Bay

1. Introduction

Phragmites australis is an invasive species of special concern in the wetlands of the North American Great Lakes (Marks et al., 1994; Galatowitsch et al., 1999). It is a cosmopolitan species of wetland grass native to every continent but Antarctica. The genotypes native to North American have been joined by an aggressive introduced genotype, apparently brought by European settlement (Lynch & Saltonstall, 2002; Saltonstall, 2002). The primary concern relative to *Phragmites* invasion is the loss of species richness and consequent potential for extinction and loss of biodiversity (Havens et al., 1997; Chambers et al., 1999).

To understand the magnitude and distribution of *Phragmites* invasions requires research in a spatial context at several scales. At the scale of individual stands, field survey is essential to understand the myriad factors which drive invasions and the environmental changes that follow. It is equally important to determine if these small scale patterns are consistent across a wider geographic scale and to tie these small scale patterns to the larger patterns of invasion. The appropriate scale, uniformity, and timeliness required of these data are all but impossible to acquire with only field assessment and monitoring (Heywood, 1995).

Airborne hyperspectral sensors such as AVIRIS, CASI, HyMap and PROBE-1 have been somewhat successful in mapping vegetation at the species level (Bachmann et al., 2002; Lopez et al., 2004; Parker Williams & Hunt, 2002; Schmidt & Skidmore, 2001). However, the high cost and limited coverage of airborne sensors is a barrier to their use for wider scale management and study. Space platform remote sensors such as

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Landsat provide the wider view and lower cost needed for practical applications, but have shown less facility for distinguishing species than have hyperspectral sensors including Hyperion (Goodenough et al., 2002; Thenkabail et al., 2004). The Hyperion sensor aboard the EO-1 satellite is an experimental sensor that merges the spectral resolution of airborne hyperspectral instruments with the practicality of satellite remote sensing (USGS, 2006a). We utilized Hyperion imagery to determine if a space platform hyperspectral sensor could distinguish invasive wetland plant species, as has already been done using more expensive airborne hyperspectral sensors (Bachmann et al., 2002; Lopez et al., 2004).

In this study we tested the applicability of Hyperion for mapping monodominant stands of *Phragmites* in the coastal wetlands of the Great Lakes. We acquired a Hyperion image of the west coast of Green Bay, Wisconsin and predicted the occurrence of large stands of monodominant *Phragmites* by creating a two-class thematic map. We evaluated the *Phragmites* map with field data.

2. Methods

2.1. Study site

The Hyperion image used in this study was a 7.5 km swath within Wisconsin extending northeast from the City of Green Bay to the Michigan state border. The image intersected a 30 km section of the Green Bay shoreline centered on the Pensaukee and Oconto Rivers (Fig. 1). Hyperion imagery must be tasked in advance, and image acquisition was requested to occur between September 1 and October 15, 2004 to take advantage of more pronounced spectral differences between *Phragmites* and other wetland species in mid to late autumn (Bachmann et al., 2002; Bernthal & Willis, 2004). Actual image acquisition took place on September 4, 2004 at 11:23:53 a.m. CDT., during the first satellite overpass within this time window. Cloud cover was less than 25% of the image, and was mostly west of coastal areas.

The entire coastal study area has very level terrain, and average land elevation in the study area (178.3 m) rises only ~2 m above Green Bay (USGS, 2006b). The study area contains extensive areas of wetland and hydric soils (National Cooperative Soil Survey, 1988), and coastal wetlands expand and contract as water levels in Green Bay fluctuate in response to climate change (Harris et al., 1977). Lake levels at the time of image acquisition were 176.3 m, close to their historic low extremes (U.S. Army Corps of Engineers, 2006). Upland land cover consists primarily of hardwood forests, agricultural crops, pasture, and hayland (Wolter et al., 2006).

2.2. Data preprocessing

Hyperion has a low signal to noise ratio in comparison to airborne hyperspectral sensors, the result of signal lost to atmospheric absorption and the reduced energy available from surface reflectance at orbital altitude. In addition, detector arrays used in the Hyperion sensor were “spares” originally designed

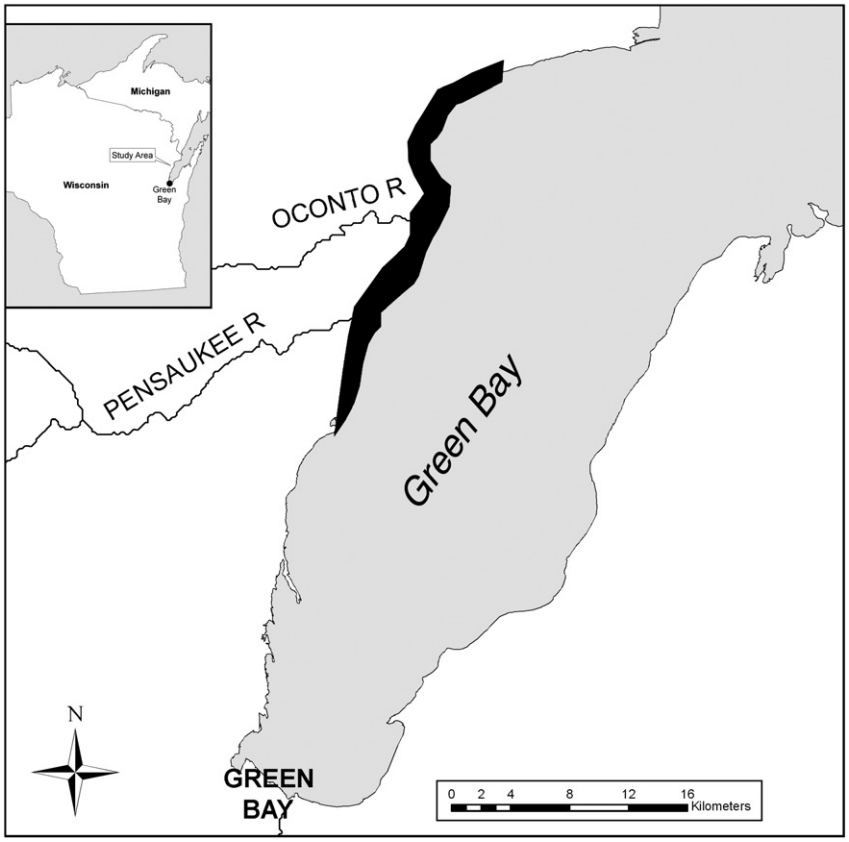

Fig. 1. Study site on the west coast of Green Bay.