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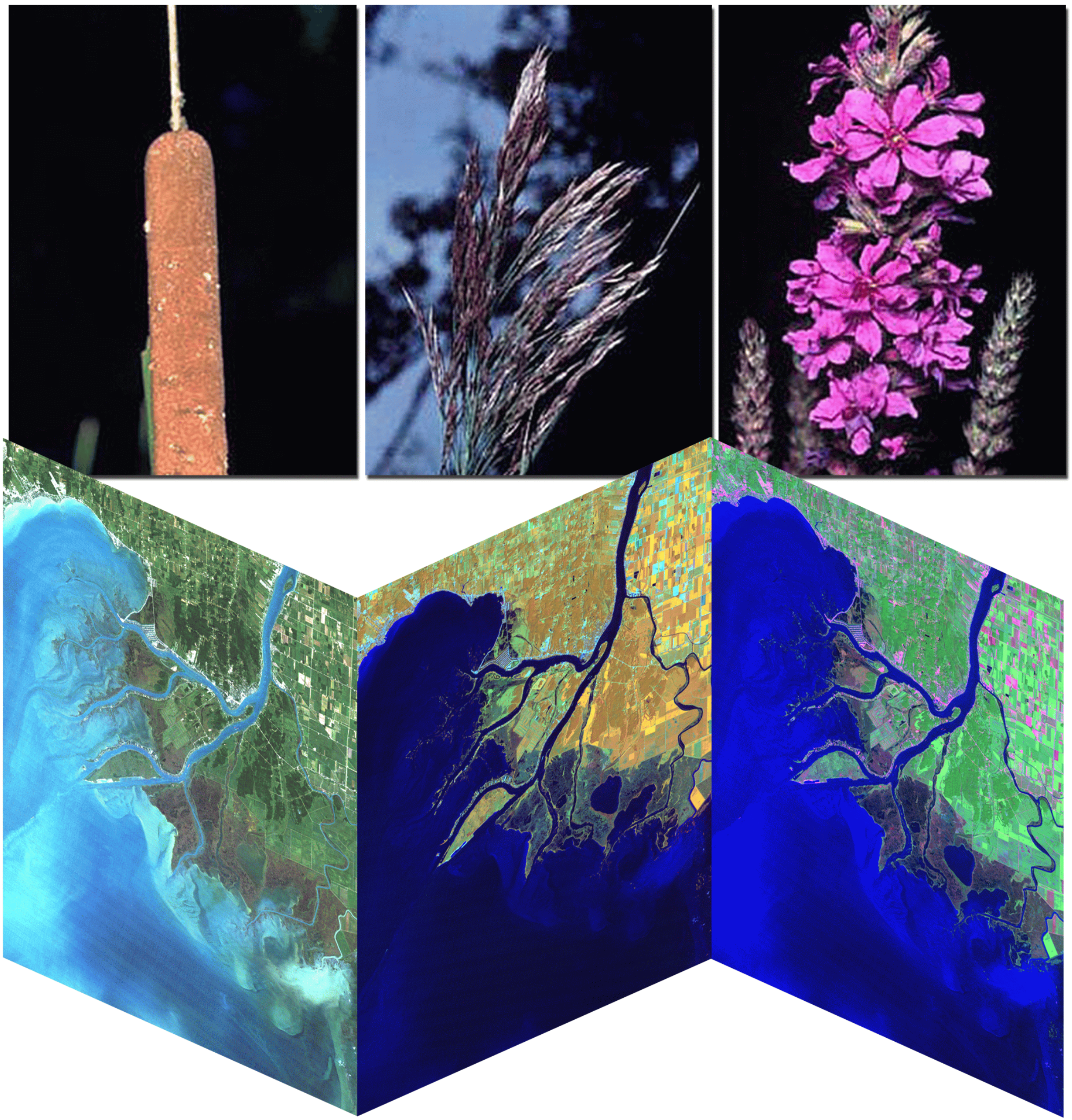
AN ECOLOGICAL ASSESSMENT OF INVASIVE AND AGGRESSIVE PLANT SPECIES IN COASTAL WETLANDS OF THE LAURENTIAN GREAT LAKES: A COMBINED FIELD-BASED AND REMOTE-SENSING APPROACH

RESEARCH PLAN



AN ECOLOGICAL ASSESSMENT OF INVASIVE AND AGGRESSIVE PLANT SPECIES IN COASTAL WETLANDS OF THE LAURENTIAN GREAT LAKES: A COMBINED FIELD-BASED AND REMOTE-SENSING APPROACH

RESEARCH PLAN

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Cover Images: (Top - left to right) reproductive plant parts of *Typha* spp., *Phragmites australis* (Cav.) Steudel, and *Lythrum salicaria* L. (Bottom) September 5, 1992 Landsat Thematic Mapper (TM) image of St. Clair River Delta [Michigan, USA and Ontario, Canada]. Three TM images (left to right) using natural color band combination (R=3, G=2, B=1), land-water definition band combination (R=4, G=5, B=3), and band combination that increases the detection of moisture in vegetation and soils (R=6, G=4, B=2). *Phragmites australis* and *Typha* spp. are abundant throughout the coastal wetlands of the St. Clair River Delta.

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PROJECT DESCRIPTION

Purpose

The aquatic plant communities within coastal wetlands of the Laurentian Great Lakes are among the most biologically diverse and productive systems of the world. Coastal wetlands have been especially impacted by landscape conversion and have undergone a marked decline in plant community biological diversity in the past. The loss of biological diversity in coastal wetland plant communities coincided with an increase in the presence and patch-dominance of invasive (i.e., non-native and opportunistic) and aggressive (i.e., native and opportunistic) plant species. The loss of biological diversity, by definition, may be the result of the increased presence of invasive and aggressive plant species, and other ecosystem research suggests that such invasive and aggressive plant species may be the result of general ecosystem stress in coastal wetlands (see "Theoretical Basis of Project"). Thus, such losses of biological diversity in the plant communities of Great Lakes coastal wetlands may be related to changes in the frequency of landscape disturbance within a wetland or on the edges of wetlands (e.g., road fragmentation of wetland ecosystems, conversion of wetland ecosystems to agriculture, or wetland hydrology alterations). Little is known about such ecological relationships in the Great Lakes, especially at the lake-basin scale. The purpose of this study is to examine some of the landscape-scale ecological relationships by quantifying the extent and pattern of invasive/aggressive plant species and testing for substantive relationships with local landscape disturbance in the past. Remote sensing technologies may offer unique capabilities to measure the extent of these invasive and aggressive species over a large area. Our approach is to use ground-based vegetation sampling to calibrate remote sensing data, to develop spectral signatures of invasive/aggressive species that may then be used to address the ecological vulnerability of coastal wetlands. This study will focus on coastal wetlands along the coastal regions of Lake Michigan, Lake Huron, Lake St. Claire, and Lake Erie that represent a full range of disturbance conditions in the lake basins, but may also include coastal areas of the other Great Lakes (Figure 1). The outcome of this study will help managers throughout the Great Lakes region target vulnerable coastal wetlands in need of restoration or protection, an important component of improving the water quality and ecological integrity of the Great Lakes Ecosystem. This project will also produce a method that could be used by environmental managers to monitor the progress/success of wetland rehabilitation and restoration projects where measures are taken to control or eradicate aggressive plant species.

Rationale/Need

This project is the first step needed to identify the extent of wetlands being stressed by invasive and aggressive plant species throughout the Great Lakes basin. Depending on the sensor of choice, the rate of invasion might be detectable utilizing the techniques developed during this study. If this project is successful in creating a remote sensing protocol capable of identifying the extent of these species' occurrence, this protocol could also be used for inland wetlands, as well as other coastal wetland locations. This project is supported by the management of the U.S. EPA Great Lakes National Program Office, the U.S. EPA Region 5 Wetlands group, and the U.S. EPA Region 5 Critical Ecosystems Team. These offices have indicated that staff wetland scientists and ecologists would be available to support the field component of this project.

Both Great Lakes coastal wetlands and invasive species have been identified by managers and scientists within the international Great Lakes basin as important indicators of the ecological health of the Great Lakes basin. These indicators have been proposed at the international forum of the State of the Lakes Ecosystem Conferences and are available at the following Internet web sites: http://www.epa.gov/glnpo/solec/98 or http://www.cciw/ca/solec/intro.html.

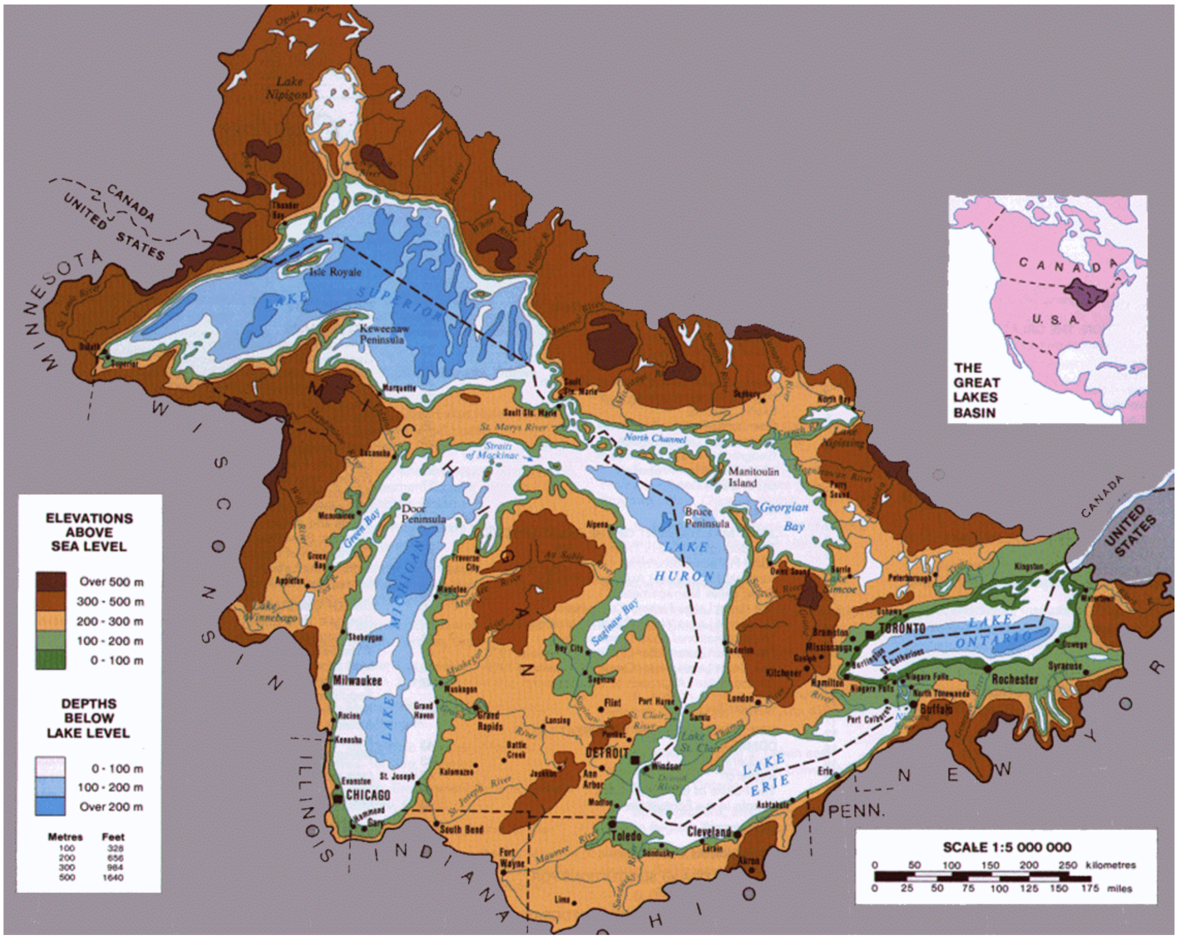

Figure 1. Coastal wetlands for this study are along the coastal regions of Lake Michigan, Lake Huron, Lake St. Claire, and Lake Erie, but may also include coastal areas of the other Great Lakes (GLNPO 1995).

Theoretical Basis of Project

Landscape Ecology

Disturbance theory suggests that the intensity and duration of disturbance within an ecosystem is a key factor in the loss of ecological integrity (Connell and Slatyer 1977, Rapport 1990, Keddy et al. 1993, Opdam et al. 1993). One of the potential mechanisms for the loss of ecological integrity may be the decline in biological diversity of an ecosystem, through the invasion of opportunistic species (Odum 1985). The loss of plant biological diversity in coastal wetlands of the Laurentian Great Lakes has been widely described as a result of increased dominance of opportunistic plant species (e.g., Stuckey 1989).

Although not the only invasive and aggressive plant species present in the Great Lakes, the three opportunistic emergent plant species to be studied (*Lythrum salicaria* L., *Phragmites australis* (Cav.) Steudel, and *Typha* spp) are frequently observed throughout many of the Great Lakes coastal wetlands. *Lythrum salicaria* (Figure 2) is a flowering perennial dicot that was imported from Europe in the early 1800's for its colorful flowers (Voss 1985). *Phragmites australis* (Figure 3) and *Typha* spp. (Figure 4) are flowing perennial monocots that are both native to North America and often dominate the vegetation of coastal wetlands. Although there are three species of *Typha* encountered throughout the Great Lakes, for the purposes of this study they are similar enough to analyze as a single taxa. The three cattail species typically encountered in the Great lakes are *Typha latifolia* L., *Typha angustifolia* L., and a hybrid of the two species *Typha* x *glauca* Godron (Voss 1972). *Lythrum salicaria* reproduce by seed and stolons; *Phragmites australis* reproduce by rhizome or stolon but also produce copious amounts of seed that is predominantly sterile (Voss 1972); *Typha* spp. reproduce by rhizomatous growth and massive seed production (ca. 200,000 per spike). *Typha* growth in a single season from a single seed has been reported to produce a rhizome system 3 meters in diameter, with a total of 100 shoots (Voss 1972).

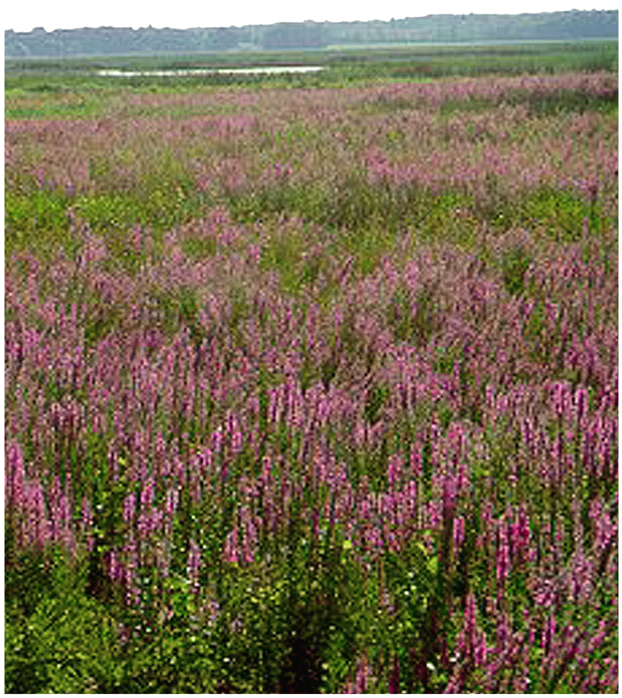

Figure 2. Typical patch of *Lythrum salicaria* in a coastal marsh (photo: The Nature Conservancy).

Figure 3. Typical patch of *Phragmites australis* in a coastal marsh.

Figure 4. Typical patch of *Typha* spp. in a coastal marsh.

In general, *Lythrum salicaria*, *Phragmites australis*, and *Typha* spp. are resource generalists that have life histories and physiological characteristics that enable them to rapidly invade new areas and flourish under environmentally stressful conditions, where other plant species can not. *Lythrum salicaria*, *Phragmites australis*, and *Typha* spp. are similar in that they are often found to dominate wetland plant communities. Therefore, the landscape ecology questions posed (in the Project Objectives section) will be tested in wetlands that are dominated by large patches of each of the three species, keeping in mind that there are distinct biological and ecological differences between the species. Expansion of the three plant species in coastal wetlands may be a benchmark for observing the potential effects of landscape disturbance on the biological diversity of wetlands because each species form large, relatively homogeneous patches that typically reach sizes in the range of 1 to 50 hectares. The expanding populations within the patches observed in the Great Lakes may be the result of increased opportunities for the migration of individuals (or genets) from small initial populations to newly opened gaps in the landscape.

Many of the opportunities for the expansion of these plant populations into landscape gaps may be the result of increased land-cover fragmentation (Forman 1995), creating small pockets of suitable invasive/aggressive plant habitat (e.g., roadside clearings, disturbed water courses, and eroded shorelines). The patch dynamics (i.e., either increases or decreases in extent) of these plant species in disturbed Great Lakes coastal areas may therefore be facilitated by the extent of patch disturbance in the vicinity of coastal wetlands. Attempts to control these plant species in Great Lakes coastal marshes (e.g., during the 1970's, 1980's, and 1990's) may have bolstered the population resiliency by increasing the proportion of ‘management resistant’ characteristics in the plant populations (Diamond 1974), acting to further select for invasive genotypes at managed wetland sites.

Some specific studies of reed patches in other regions support the patch disturbance hypothesis, but indicate that the level of disturbance may be an important factor in the process. Die-back of *Phragmites* in relatively undisturbed temperate European regions, and expansion of *Phragmites* in European areas of climatic extremes (van der Putten 1997) suggest that periodic disturbance may increase the rate and extent of expansion, such as has occurred in some coastal areas of the Laurentian Great Lakes. Periodic stress may actually allow for the formation of relatively small, interconnected metapopulations, where gene flow between patches maintains the genetic diversity that might otherwise decline (i.e., in relatively large inbred populations). When such populations become unable to bridge the gaps between populations, at the advanced stages of patch isolation, entire populations may become locally extinct (Opdam 1990).

Landscape Change Detection

The inherent complexity of the numerous biotic and abiotic variables involved in the process of landscape change has prompted research and development of specialized sensors and processing techniques. These sensors and techniques have been necessary to gather sufficient data to determine ecological relationships over large areas of the landscape. There are also many examples of the use of historical maps and aerial photographs to assess patch fragmentation and ecological characteristics of the landscape (e.g., MacArthur and Wilson 1967, Howard 1970). Airborne data is also useful for determining the ecological effects of abiotic environmental factors (e.g., Lyon and Drobney 1984, Lyon and Greene 1992). Recently, ecological studies have successfully utilized data from more sophisticated sensors (e.g., Color Video, Landsat MultiSpectral Sensor and Thematic Mapper), automated image processing software/techniques, and geographic information systems. These tools have been used to describe better the identity of materials within the landscape, and to describe landscape change (Jones et al. 1997, Heggem et al. 1999). However, most of these tools are new and the application of these sensors and techniques to wetland detection and analysis has not been fully explored.

The spectral and spatial detection characteristics of the 5 sensors to be used in this study are listed in Table 1. Sensor comparisons are generalized to allow for comparison between sensors, and to highlight the information utilization trade-offs between sensors. For example, among the sensors utilized in this study, the imaging spectrometer (AVIRIS) offers the greatest spectral resolution and the Color Video data offers the greatest spatial resolution. The range of spectral and spatial resolution among sensors illustrates a fundamental trade-off when considering sensor design and use. The trade-offs between sensor capabilities is the basis for ongoing research to determine the ideal combination of spatial, spectral, and radiometric characteristics for each application of remote sensing technologies (Schott 1997). The data types utilized in this study have been used to answer many landscape ecology questions, however cross-sensor applications of these sensors have not been widely used for wetland ecosystem detection or for landscape disturbance research, especially at the lake basin scale.

Table 1. Comparison of Some Relative Sensor Characteristics (as utilized for this study)

Passive Sensor Type	Spectral Resolution	Spatial Resolution
CV	Coarse	Fine
AVIRIS	Fine	Fine to Moderate
MSS	Coarse	Coarse
TM	Coarse	Moderate

*RADAR is an active sensor that can transmit and receive signals through clouds, haze, smoke, and darkness, and obtain high quality images of the Earth in all weather at any time.

PROJECT OBJECTIVES

Three fundamental wetland detection questions will be addressed by the study:

1. Can airborne color video (CV) data (Figure 5), airborne visible infrared imaging spectrometer (AVIRIS) data (Figure 6) or other hyperspectral data, satellite thematic mapper (TM) data (Figure 7), radio detection and ranging (RADAR) data (Figure 8), satellite multispectral scanner (MSS) data (Figure 8), or other selected remote sensing data (e.g., MODIS, ASTER, or CASI) be used to accurately identify patches of purple loosestrife (*Lythrum salicaria*), giant reed grass (*Phragmites australis*), or cattails (*Typha* spp.) in the coastal wetlands of the Great Lakes?

2. Which sensor(s) is(are) most effective for identification of vegetation patches of the above species?
3. What is the detection accuracy of each sensor (or sensor combination), using ground-based plant community data as truth?

Four fundamental landscape ecology questions will be addressed by the study:
1. What is the range of landscape stress among coastal wetland study sites, as evidenced by historical land-cover change in the wetland vicinity (early 1970's - 1990's)?
2. What are the ecological relationships between landscape stressor(s) and the extent of the invasive/aggressive plant species in the coastal wetlands of the Great Lakes?
3. What Great Lakes coastal wetlands are the most threatened by invasive/aggressive plant species and what is the areal extent of *Lythrum salicaria*, *Phragmites australis*, and *Typha* spp. at these sites?
4. Can this project serve as the baseline for measuring the rate of expansion or die-back (i.e., increasing or decreasing patch size) of invasive/aggressive plant species?

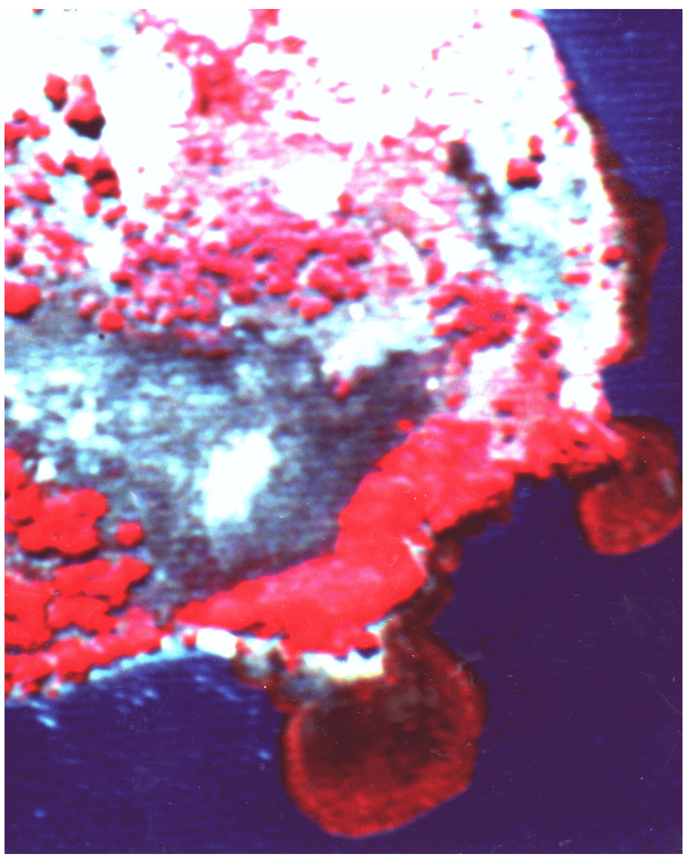

Figure 5. Airborne color video (CV) data of coastal marsh, and upland woods.

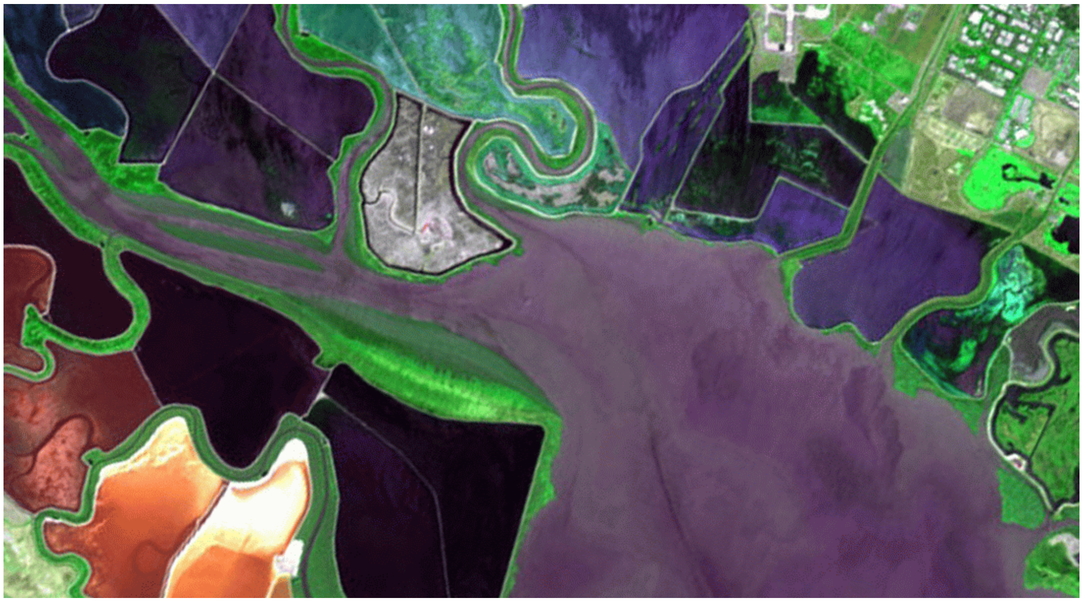

Figure 6. Airborne visible infrared imaging spectrometer (AVIRIS) data of a coastal area, including marsh, agricultural, and urban areas.

Figure 7. Landsat thematic mapper (TM) data of a coastal area, including marsh, wooded, agricultural, and urban areas.

Figure 8. Radio detection and ranging (RADAR) data of a coastal area, including marsh and developed areas.

Figure 9. Satellite multispectral scanner (MSS) data including marsh, wooded, agricultural, and urban areas.

TECHNICAL APPROACH

Overview

The approach of this study is to A) determine which, if any, of the three study-species are identifiable using remote sensing data, and by which sensor(s); B) identify coastal wetlands (per Cowardin et al. 1979) in the Great Lakes that are dominated by each of the invasive or aggressive plant species; C) establish a group of 'gradient test sites' that range from high to low dominance of each invasive or aggressive species, using a stratified random sampling method; D) determine how historical land-cover change among the 'gradient test sites' is related to the presence and the spatial extent of existing invasive or aggressive species patches. Note that, depending upon the outcome of the preliminary sensor/species studies, all of the species and sensors may not be required to complete step D.

Calibration of the remote sensing data will be accomplished by mapping the vegetation in coastal wetland plant communities that are known a priori to contain patches of either purple loosestrife, giant reed grass, or cattails. During vegetation sampling the field team will use a Global Positioning System (GPS) to delimit the boundary of invasive/aggressive species patch(es) within the wetland, and sample fixed points within the core of the patch(es) and on the perimeter using a hand-held spectroradiometer and GPS. These field data will be used in the laboratory to calibrate the AVIRIS (or other hyperspectral) data from over-flights scheduled for the same time period. Within the patches dominated by the above species (and on the periphery of each patch), standard cover estimates, and stem density measurements will be performed using a quadrat method (Mueller-Domboise and Ellenberg 1974, Barbour 1987). Field data will also be used to test the efficacy of using CV, AVIRIS, TM, MSS, and/or RADAR (or other selected) sensor data for identifying the patches of invasive and aggressive plant species in coastal wetlands.

Sensor accuracy assessments from the study will provide information about which sensor(s) are suitable to detect the invasive/aggressive species, and will be used to determine which type(s) of remote sensing data will be most useful to complete the site analyses. Ground-based sampling, maps, and aerial photographs will be used to accuracy-assess wetland characteristics determined from remote sensing data.

A stratified, random sampling design will be used to select wetlands for verification of the remote sensing methods for detection of invasive/aggressive plant species and to attain the objective of assessing the extent and degree of invasion into coastal wetlands of the Great Lakes. Each wetland will be assessed for the presence of large homogeneous stands of the three study plant species during summer sampling using information from the sensor comparison portion of the study. The field site selection and field work will be coordinated with wetland ecologists in the local area.

North American Landscape Characterization (NALC) data from the 1970's to the 1990's (i.e., Landsat Multispectral Scanner data), along with TM data collected during the 1990's and 2000's will be used to develop land-cover maps. The land-cover maps will be used to quantify 30 years of land-cover change in the vicinity of the coastal wetlands studied. Multivariate statistics (e.g., multiple regression and multiple analyses of variance) will be used to test for substantive relationships between land-cover change and the invasive/aggressive plant characteristics at wetland study sites (i.e., all appropriately sampled wetland study sites).

Project Tasks

1. Locate coastal wetlands along the shore of the Laurentian Great Lakes in coordination with local wetland ecologists.

2. Use a stratified, random sampling protocol to determine the spatial extent of homogeneous stands of *Lythrum salicaria*, *Phragmites australis*, and/or *Typha* spp. among those wetlands selected in Task 1, and ground-survey sites

3. Develop and test efficacy of utilizing the selected sensors to locate the patches of wetland plants delineated in Task 2.

4. Determine and map the spatio-temporal land-cover change (1970's - 1990's) adjacent to the wetlands selected in Task 2

5. Identify any landscape-ecological relationships between invasive/aggressive plant patch configuration and land-cover change that has occurred (1970's - 1990's) in the vicinity of coastal wetland study sites

Non-Exclusive List of Data Utilized in the Study

Airborne

Wetland Inventory Maps (i.e., Ohio, Michigan, Wisconsin, or National Wetland Inventories). These digital maps are currently available and will be used to locate and verify locations of coastal emergent wetlands.

Aerial Photographs. These data will vary by region and historical availability. Color infra-red photographs as stereo-pairs will be the ideal selection criteria but final selection will depend upon availability. These data are available from a variety of historical photograph sources and will be obtained from the appropriate government offices and distributors. The ideal range of scales are from approximately 1:1000 to 1:24,000, however scales up to 1:40,000 may be used if finer scales are unavailable.

CV. These data are available from Positive Systems Inc., Whitefish, Montana, and will be acquired from low altitude fixed wing aircraft. Digital image data are available as three visible bands (RGB) and 1 near infra-red band, with sub-meter spatial resolution capability. This system is based on the True Color Digital Camera System, developed by the Landscape Ecology Branch and the U.S. Department of Agriculture (Everitt et al. 1996).

AVIRIS. These data are available from NASA/JPL , Pasadena, California, and may be acquired from mid-altitude fixed wing aircraft. Digital image data are available in 224 bands in the visible and infra-red regions of the spectrum, with a spatial resolution range of 3.5 to 20 meters.

Hyperspectral Mapper (HyMap). These data are available from the HyVista Corp., North Ryde, Australia and may be acquired from low altitude fixed wing aircraft. The sensor is a commercial system with 126 spectral bands at approximately 15 nm spectral resolution and spatial resolutions of 3-10 m. The sensor operates in a 3-axis gyro stabilized platform to minimize image distortion. Geolocation and image geocoding is achieved with GPS and an integrated inertial monitoring unit.

Satellite

Landsat TM. These data are available from EROS Data Center, Souix Falls, SD, and are acquired from earth orbit. Digital image data are available in 3 visible bands (Red, Green, and Blue), 1 near infra-red band, and 2 mid-infra-red bands with a spatial resolution of 30 meters. There is also 1 thermal band with a spatial resolution of 120 meters.

Landsat MSS (e.g., NALC). These data are available from the joint EROS Data Center/LEB North American Landscape Characterization (NALC) database that resides at the LEB facility. These data were acquired from earth orbit and are processed to facilitate land-cover change analyses (i.e., minimal cloud cover, co-registered decadal images). Digital image data are available in 2 visible bands (Red and Green) and 2 near infra-red bands, and have an approximate spatial resolution of 80 meters.

RADAR. These data will be obtained from the RADARSAT-1 orbiter. RADARSAT-1 is an advanced Earth observation satellite project developed by Canada. RADARSAT-1 is equipped with a Synthetic Aperture Radar (SAR). The SAR is a microwave instrument that can transmit and receive signals through clouds, haze, smoke, and darkness, and obtain high quality images of the Earth in all weather at any time. This provides an advantage over observation by aircraft and optical satellites under sub-optimal weather conditions. Depending upon the operation mode, RADAR data has a spatial resolution of 10 meters to 100 meters. Data from different sensors may also be merged with RADAR bringing in the concept of multi-sensor data fusion. For example, multi-spectral optical data can be combined with RADAR imagery. The optical data (e.g., MSS) can provide spectral information for discriminating surface cover types and the RADAR imagery can be used to detect landscape structural details (Jensen 1996, Howarth et al. 1997).

GPS. These data are available from uplink to global positioning satellites, using a Trimble Pro XRS receiver/data-logger. Position data will be downloaded in the field to the GPS receiver/data-logger, along with site identification information (GPS accuracy is sub-meter).

Field and Other Data Sources

Spectroradiometer. These data are available from field measurements using a FieldSpec Pro Spectroradiometer, Analytical Spectral Devices, Inc., Boulder, CO. The spectroradiometer will be positioned above the plant canopy using a tripod system, and the position of the reading will be logged automatically with the GPS (above).

Digital coverages. Digital map coverages will be obtained from a variety of sources and will contain landscape data including (but not limited to): hydrology, soil chemistry, fertilizer application, pesticide application, geology, topography, water chemistry, land cover, population, roads, political boundaries, and biological characteristics.

Gradient Analyses

A fundamental component of the study design is the selection of a sufficient number of study sites to account for the full range of disturbance conditions (Green 1979, Karr and Chu 1997) that are present in coastal wetlands of the Great Lakes. An stratified, random sampling design will be used to attain a gradient of potential wetland disturbance, ranging from least-impacted sites to potentially impaired sites. An initial targeted sampling technique may be necessary to initially stratify the gradient into coarse categories (e.g., regions that are likely to have substantial land-cover change along coastlines and regions that are likely to have lesser amounts of land-cover change along coastlines). Initial studies, prior knowledge of local experts, existing data, and publication of prior work in Lake Michigan, Lake Huron, Lake St. Claire, and Lake Erie indicate that coastal wetlands have sufficiently large stands of the study-species, sufficient variability in patch size among sites, and sufficient variability of adjacent land-cover characteristics to successfully perform the gradient analyses.

The land-cover gradient will be determined from the land-cover maps produced from historical (1970's - 1990's) satellite imagery or other available land-cover data sets. Table 2 lists the minimum Anderson (1976) "Level 1" land-cover class detail to be used for the analysis of the land-cover gradients. Land-cover gradient(s) will be determined from the spatio-temporal characteristics of land-cover change in the vicinity of each wetland site. Historical data can be used to verify the duration of land-cover change in an area and to assess the rate of change since the 1970's. The gradient(s) of land-cover change (the 'stressor' variable(s)) will then be compared to the patch characteristics of the applicable plant species (i.e., the response variables). The relationships between the stressor and response variables will be tested with multivariate statistics (e.g., multiple regression or multiple analyses of variance) to determine ecologically relevant and statistically significant relationships. The comparison of contemporary plant species patch characteristics to temporally static land-cover change (i.e., variability among sites) will be performed as well as an analysis of land-cover change from the 1970's to 1990's (e.g., rate of change among sites). Each of these gradient analysis techniques solves the problem of having only limited availability of plant species data at the field sites in the 1970's, 1980's, and the early 1990's.

Table 2. Anderson Land Cover Classes

Land-Cover Class	Regional Examples
Urban or Built-Up Land	Shopping center, parking areas, sub-urban area
Range Land	Grassy 'old field'
Forest Land	Forest
Water	Pond, lake, stream
Agricultural Land	Corn, soybean row crop
Barren Land	Gravel pit, beach
Wetland	Riverine wetland forest, coastal marsh

Data Management

All of the study results, data sets (including metadata), and final project documents will be made electronically available at the time of final report publication. These data will also be made available on the Landscape Ecology Branch web site, and directly linked to the EMAP Web site. These activities will comply with ORD guidance on federal data and metadata standards.

Quality Assurance/Quality Control

Accuracy of data and procedures is an important aspect of this research and efforts to ensure the quality of the final products are incorporated into every step of the project. These quality control procedures include verification of geographic coordinates and projection information on map and imagery products. After data transfer from contributors outside the Landscape Ecology Branch is completed, data will be recorded and routinely checked for accuracy and completeness. Accuracy assessment of land-cover classifications will be performed at the Environmental Photographic Interpretation Center in Reston, Virginia using high resolution aerial photographs of the study areas and GPS data collected at field sites. A contingency table (i.e., a confusion matrix) will be generated to describe errors of omission and errors of commission during classification of the imagery. All field and laboratory equipment will be regularly calibrated per the established laboratory schedule. This project plan has passed a peer review by experts in remote sensing, geographic information systems, and landscape ecology, and a summary of their comments and reconciliation of concerns is available from the Principal Investigators upon request.

PRODUCTS

A. Project Report:

An Ecological Assessment of Invasive and Aggressive Plant Species in Coastal Wetlands of the Laurentian Great Lakes: A Combined Field-Based and Remote-Sensing Approach

B. Refereed journal articles:

#1 *Coastal wetlands detection in the Laurentian Great Lakes: A cross-sensor test*

#2 *Identification of invasive and aggressive plant species in coastal wetlands of the Laurentian Great Lakes: A cross-sensor test*

#3 *The landscape-ecological relationships between land-cover change and invasive and aggressive/invasive plant species in the coastal wetlands of the Laurentian Great Lakes*

C. Images/data from all wetland study sites

D. Historical land-cover maps

SCHEDULE, MILESTONES

Table 3. Project Milestones

Time Period	Activities
2000 April - June	Investigation of MSS (NALC) and TM scene availability and selection of scenes
2000 July 13	Project proposal submitted for U.S. EPA and external peer review
2000 July - Sept	Site reconnaissance with Region 5 scientists, GPS preliminary wetland sites, preliminary vegetation field-sampling
2000 Oct. - Dec.	Initial team member meetings to develop sampling protocols, site selection
2001 Jan.	Research Plan published
2001 Feb. - April	Order site maps and aerial photographs, order available satellite imagery, schedule overflights, preliminary site reviews with team members, ensure site access
2001 May - Sept.	Field/remote-sensing data collection
2001 Oct. - Dec.	Processing of summer 2001 remote sensing data (CV, AVIRIS, RADAR, or other selected sensor data), analyses of vegetation data and study site GPS/spectroradiometer data. Processing of NALC and TM data for land-cover change analyses
2002 Jan. - April	2002 study site selection with team members, ensure site access, protocol effectiveness team meetings
2002 May - Sept.	Field/remote sensing data collection
2002 Oct. - Dec.	Processing of summer 2002 remote sensing data, analyses of field data
2003 Jan. - June	Sensor data validation assessment using ground-based and other data
2003 July - Dec.	Analyses of patch characteristics, complete project report, develop and prepare manuscripts for refereed journal articles

PROJECT BUDGET AND JUSTIFICATION

Overview

The budgetary requirements to conduct this project are provided by the U.S. EPA Region 5 R-EMAP, with in-kind support from the Landscape Ecology Branch. The in-kind services include selection and processing of the remote sensing data, GIS analysis of patch characteristics of the wetlands, statistical analysis and ecological interpretation of the land-cover change data, technical writing and editing, production of final maps, production of final images, and field work that will be coordinated with local wetland ecologists.

Project Justification

Geographic and Remote Sensing Data and Services

Maps in digital or hard-copy format will be used to validate the location of wetland sites and the identity of features in the landscape (e.g., roads) and will aid in the GPS mapping of the sites. Digital map data will be used for producing relevant GIS coverages that, when combined with the land-cover classifications, will aid in the description of the wetland site and the surrounding landscape. Aerial photographs will be used for reconnaissance of potential field sites before visiting site, while scouting a site, and during the land-cover classification portion of the study. CV, MSS, TM, RADAR, and AVIRIS (or other selected) data will be used to locate wetlands, determine boundaries of wetlands, and to measure patches of *Lythrum salicaria*, *Phragmites australis*, and *Typha* spp. within wetlands of the Laurentian Great Lakes. MSS, TM, and RADAR (or other selected sensor) data will also be used to produce land-cover maps for change analyses.

Map Products

Land-cover maps from the 1970's through the 1990's will be used to develop land-cover change images, which will subsequently be used to determine the relationships between plant species patch configuration and local landscape change.

Field Sampling

Field measurement of the boundaries of each patch of plant species is necessary for comparison to the remotely sensed data. Field measurements will primarily involve GPS recording of the patch boundary, stem count sampling within the core area of the patch, estimating percent cover in the core area of the patch, and spectrometry in the core area of the patch. The spectrometry data are required to develop accurate spectral signatures from the hyperspectral data.

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PROJECT MANAGEMENT

The Landscape Ecology Branch

The Landscape Ecology Branch (LEB) is located on the campus of the University of Nevada, Las Vegas and is under the U.S. EPA's Office of Research and Development, Environmental Sciences Division. The Branch employs 32 professionals, including biologists, research ecologists, engineers, statisticians, GIS specialists, remote sensing specialists, photo-interpreters, data management specialists, graphic artists, and procurement specialists. The Branch has robust hardware and software capabilities (e.g., ESRI-Arc/Info, ESRI-ArcView, ERDAS-Imagine, RSI-ENVI) that enable the efficient processing and analysis of data. The Branch employs 6 full-time Ph.D. researchers. The LEB possesses a modern laboratory and is supported by the resources and facilities of the Environmental Sciences Division and the U.S. EPA Environmental Photographic Interpretation Center in Reston, Virginia.

The LEB conducts research in the field of landscape ecology and related disciplines, develops landscape assessment and characterization applications, and develops tools and methods for solving regional environmental problems. Many of these projects involve the analysis of ecosystem and watershed vulnerability to human-induced stresses. The primary goal of the LEB is to develop tools for: 1) understanding and forecasting ecosystem trends; 2) assessing the ability of an ecological resource to provide desired benefits; 3) anticipating emergency environmental problems; 4) monitoring and documenting progress in maintaining and restoring ecosystems. LEB research includes developing ecologically-meaningful indicators of landscape condition and trends related to endpoints of importance to the EPA; developing, applying, and transferring tools for measurement, assessment, and prediction of the sustainability and vulnerability of landscapes at multiple spatial and temporal scales; maintaining pace with rapidly developing science and technology of remote sensing. Current LEB projects include applied research in Arizona, Arkansas, California, Colorado, Delaware, Georgia, Idaho, Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Vermont, Virginia, Washington, West Virginia, and Wisconsin.

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