Annual Report

"How do plant species invasions affect water quality services performed by Great Lakes coastal wetlands?"

March 2009-February 2010

Principal Investigator
Include name, title, institution, address, city, state, zip code, telephone, fax, and email.

Tuchman, Nancy C. Professor, Dept. of Biology, and Director, Center for Urban Environmental Research and Policy, 6525 N. Sheridan Rd., Chicago, IL 60626. ph: 773-508-2475; fax: 773-508-3646; ntuchma@luc.edu

Co-Principal Investigator(s)
Include name, title, institution, address, city, state, zip code, telephone, fax, and email.

Larkin, Daniel. Conservation Scientist, Community Ecology & Smith Family Curator of Native Habitats, Chicago Botanic Garden, and Adjunct Assistant Professor, Northwestern University, 1000 Lake Cook Rd, Glencoe IL 60022, 847-835-6931; dlarkin@chicagobotanic.org

Geddes, Pamela. Post-doctoral Fellow, Dept. of Biology, 6525 N. Sheridan Rd., Chicago, IL 60626, ph: 773-508-3289; fax: 773-508-3646; pgeddes@luc.edu

Treering, David, GIS Specialist, Center for Urban Environmental Research and Policy, 6525 N. Sheridan Rd., Chicago, IL 60626, ph: 773-508-8254, fax: 773-508-3646; dgoldb2@luc.edu

Abstract
Summarize project and accomplishments or results (250 words).

Wetlands supply numerous ecosystem services including flood control, habitat for flora and fauna, and nutrient removal. Nutrients such as nitrogen flow into aquatic ecosystems from agricultural and residential regions and can create vast areas of eutrophication and hypoxia. Wetlands can remove much of this nitrogen through the process of denitrification, transforming NO_3- to N_2O or N_2 gas. N_2O gas is a potent greenhouse gas while N_2 gas is harmless, making up most of the atmosphere. In order to produce the higher quality N_2 gas, wetlands must be inundated with water, creating anoxic conditions in soil sediments ideal for denitrifying bacteria. However, invasive species can greatly alter the native wetland flora and fauna as well as the local hydrology and ecosystem processes. We are investigating the effects that the invasive plant, *Typha x glauca*, has on the overall quantity of denitrification and the quality of the gases produced (N_2 vs. N_2O). Our first year results suggested that *Typha* litter may provide organic carbon for denitrifiers, but over time, litter accumulation may increase redox potential, eventually limiting rates of denitrification in older sites. In year two, we examined the

effects of *Typha* on wetland ecosystem properties along a stand-age gradient. Preliminary results indicate that with increased stand age, there were no significant relationships with denitrification quantity or quality, whereas *Typha* density, litter mass, and soil organic matter increased, and species diversity decreased. These data provide important information that can be utilized by wetland managers to maximize the ecological benefits of management techniques.

Introduction

Include goals and objectives of the project.

Invasive plants generally produce large amounts of biomass due to increased productivity. As the invasive plant's production competitively excludes native plant communities, this biomass can, over time, change the ecosystem's soil composition and microbial community (Ehrenfeld, 2003). Invasive cattails (*Typha x glauca* (hereafter referred to as *Typha*)) produce large amounts of biomass in the form of standing dead plant material (litter). This dense litter covers the ground and causes a decrease in native plant diversity (Angeloni et al., 2006; Boers et al., 2007; 1st and 2nd Year data). Increased productivity also causes an increase in soil organic matter. Where *Typha* was present, Angeloni et al. (2006) saw a four-fold increase in soil organic matter, a fourteen-fold increase in ammonium, a ten-fold increase in nitrate, and significant increases in bacterial species richness as compared with uninvaded areas. Tuchman et al. (2009) found decreases in species richness and water depth and increases in litter biomass, soil organic matter, NH_4, NO_3-, and PO_4 associated with *Typha* invasion.

Studies examining effects of invasive plant species on denitrification rates are lacking, although observed increases in NO_3- suggest that invasions may increase rates of denitrification (Ehrenfeld, 2003). Jankowski (2006) found increased rates of denitrification in *Typha*-invaded areas likely due to increases in soil carbon and nitrogen as a result of invasion. However, as *Typha* biomass in the form of litter is deposited onto the wetland soils, a resulting decrease in water level and an increase in redox potential may be observed, possibly reducing any further increases in denitrification rates. As the invasion continues, large decreases in rates of denitrification may be observed as the elevation of the wetland increases. Similar wetland elevation changes have been observed in ecosystems invaded by *Phragmites australis* (Weinstein and Balletto, 1999; Rooth et al., 2003). It is necessary to assess the impacts of *Typha* on wetlands and wetland services as invasions have the potential to alter and even eradicate habitat and services which are necessary for healthy ecosystem functioning. Further, studying *Typha* invasions may lead to effective management strategies to control and possibly prevent invasions in the future.

Objectives:

1) Characterize the relationships between invasive species and water quality ecosystem services in Great Lakes area wetlands.

2) Develop site-specific management recommendations for optimizing ecosystem services based on improved understanding of invasive species effects of denitrification.

3) Provide educational and research opportunities for graduate and undergraduate students centered on improving the scientific basis for stewardship of Great Lakes area wetlands.

Narrative Report

Annual report - The narrative should be approximately 1-2 pages. For this section, we are interested actions and accomplishment during the **calendar year**.

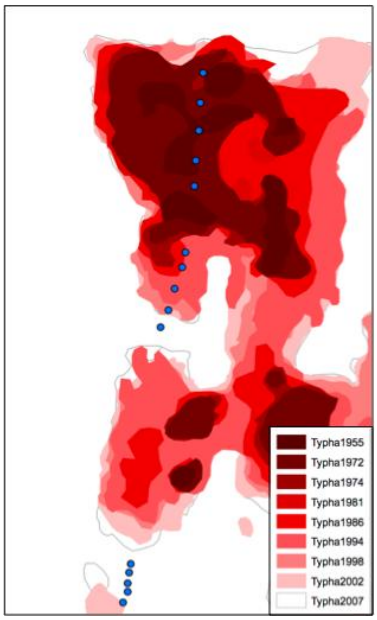

Figure 1. Map of a 2009 transect illustrating *Typha* x *glauca* stand age polygons generates using historical aerial photographs.

Research was conducted during the summer of 2009 in Chiwaukee Prairie, Spring Bluff Nature Preserve, and Illinois Beach State Park. We sought to expand on our preliminary results from 2008 which suggested that the ecological impacts and effects on denitrification processes of *Typha* would likely increase with increasing *Typha* stand age. Therefore, utilizing historic aerial imagery from 1939-2008, we determined the time of establishment of *Typha* in our study wetlands and the age of *Typha* stands. In 2009 we established research transects along stand-age gradients and collected a suite of environmental, plant community, and denitrification data, allowing for us to evaluate the correlations between measured variables and stand age (Fig. 1).

Results from 2009 confirm our hypothesis that many environmental conditions important for sustained wetland ecosystem function are significantly altered by the presence of *Typha* and the quantity of change increases with increasing *Typha* stand age. Specifically, we found that litter depth was significantly greater in plots with *Typha* ($P < 0.05$), and with increasing age of *Typha* stands, *Typha* density and soil organic matter (percent and depth) increased, while plant community diversity and species richness decreased ($P < 0.05$) (Fig. 2). These results provide further support that there are clear differences between *Typha* invaded vegetation zones and native vegetation zones and that ecologically important environmental variables change with increased *Typha* stand age. These changes fundamentally alter the wetlands and will likely contribute to changes in wetland function.

However, counter to our hypothesis and contrasting with other studies (Jankowski 2006, Tuchman unpublished), no significant correlations between stand age and denitrification quantity or quality were observed. We attribute the relatively constant denitrification rates observed in these wetlands to two principal factors: 1) the native sites at these wetlands have particularly high levels of organic matter owing to their dominance by highly productive *Carex* spp.; 2) water levels and redox did not vary with stand age as a result of local topography and hydrology. Unlike open embayment Great Lakes coastal wetlands with predominantly emergent marsh communities, high wave energy, low levels of organic matter in the native dominated portion of the wetland, and a clear elevation gradient (Angeloni 2007, Tuchman 2009), the Illinois Beach dune and swale wetlands are protected from organic sediment disrupting wave energy and water levels are relatively constant within the wetland swales.

Our denitrification results from 2009 are particularly important in the context of Great Lakes region invasive species ecology. In northern Great Lakes coastal wetlands and in emergent marsh communities *Typha* establishment has significant impacts on wetlands soils and species diversity and can also have significant effects upon denitrification rates and quality (Jankowski 2006, Tuchman unpublished), whereas, in southern Great Lakes wetlands and in sedge meadow communities, *Typha* similarly impacts species diversity, but the impacts of on denitrification may be limited. Therefore, wetlands long-invaded by *Typha* in the southern Great Lakes still appear to provide the important ecosystem function of denitrification.

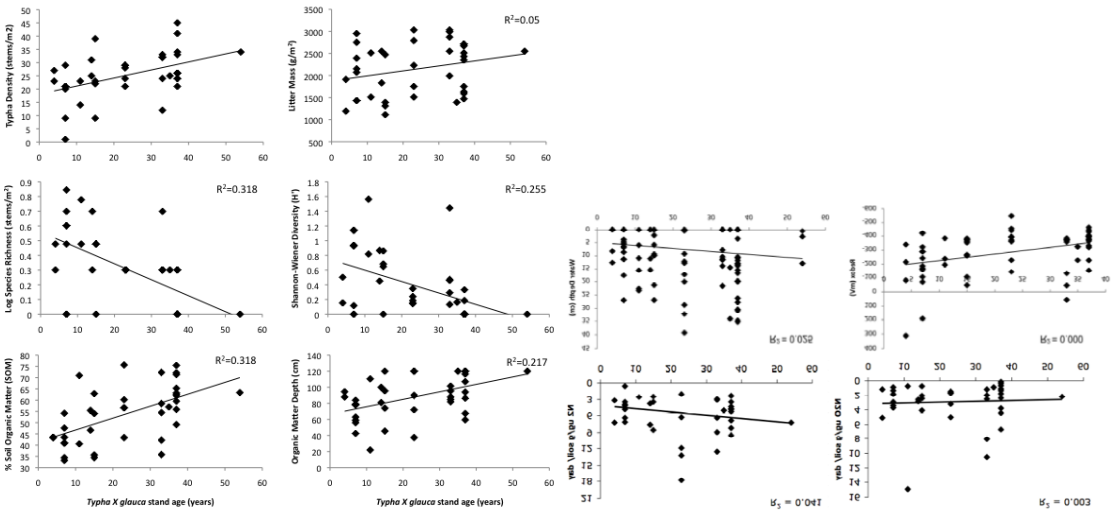

Figure 2. Simple linear regression correlations between denitrification, environmental, and plant community quality variables and *Typha* x *glauca* stand age (only plots with *Typha* included).

The stand age and ecological change correlations determined from our 2009 data were utilized to create a figure depicting the impacts of *Typha* through time (Fig. 3). This easily interpreted timeline provides information valuable to wetland managers concerned with maximizing restoration impacts with limited resources. Because many of the ecological impacts of *Typha* increase through time, we recommend that managers focus restoration activities on stands less than 11 years old.

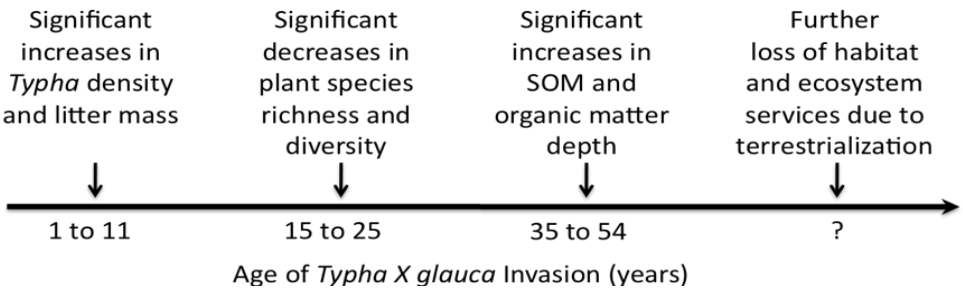

Figure 3. Timeline of *Typha x glauca* invasion showing significant ($P<0.05$) differences observed during each invasion age group. SOM is an acronym for % Soil Organic Matter.

By determining ecological correlations with the ages of *Typha* stands, we are beginning to understand how *Typha* impacts the wetland ecosystem over time with respect to ecosystem characteristics and functions. This knowledge will improve scientific understanding of invasive species and their impacts on endangered ecosystems as well as global climate change. It is also beginning to provide practical information that can be used by land managers to improve wetland restoration practices and to help combat the spread of invasive species throughout our world's wetlands.

Final report - the narrative should include methods, results, conclusions, recommendations, and other pertinent information. Focus on the project's activities and accomplishments in context of the overall project's goals. There is a limit of 20,000 characters or about 20 double spaced pages.

NOT APPLICABLE

Potential Applications or Benefits *(This includes effects this project had on industry development and productivity, resource management, user group behavior and/or scientific advancement).*
Be sure to include benefits, commercialization, and application of project results, scientific/technical advice, etc.

This project's results can be applied to management techniques which strive to maximize denitrification rates while still maintaining denitrification quality. It will also further understanding of *Typha* invasions, possibly leading to practical methods for limiting its spread and/or removing it entirely.

Keywords
Include a short list of keywords for indexing

Wetlands, Invasive Species, *Typha*, Denitrification

Lay Summary
A brief summary, 1-2 paragraphs, of your research project and important findings that would be understandable by a lay person.

Invasive plant species like the non-native cattail, *Typha x glauca*, can invade Great Lakes coastal wetlands and quickly become the dominant species. Because they are much larger plants than their native counterparts, and they are stronger competitors for nutrients, water and light, they can easily displace the native plants within a few years time. As they grow and die back at the end of each years' growing season, their dead litter accumulates and is slow to decay. Over a few decades' time, they can literally "fill in" a wetland, increasing the depth of decomposed litter and making the wetland sediments dry and more aerated. The more aerated the soils, the less efficient is the ecosystem function of denitrification. Denitrification is the process whereby sediment

bacteria remove the fertilizers that come into wetlands through surface runoff, and convert the nitrogen fertilizers to N_2 gas (a harmless gas that makes up 70% of our atmosphere). Denitrification is a very important ecosystem service that coastal wetlands provide, as it removes fertilizer nutrients from runoff, keeping it from causing overgrowth of algae and bacteria in the downstream lakes. However, when a wetland becomes invaded and dominated by *Typha x glauca,* and the wetland begins to fill in, the process of denitrification could be compromised. We hypothesize that denitrification is reduced, due to aeration of the soils, but also that it may be producing a potent greenhouse gas (N_2O) as a by-product of aerated soils, rather than producing harmless N_2 gas as a product.

Our project evaluated the soils, wetland plant communities, and the quality and quantity of denitrification in several Lake Michigan coastal wetlands in Illinois that are being invaded by *Typha x glauca*. We hypothesized that the areas that *Typha x glauca* has occupied for decades would have deep organic soils, low species diversity, reduced denitrification and will produce more N_2O than the areas where *Typha x glauca* has more recently invaded. Our research determined that *Typha* x *glauca* dramatically altered the plant communities and soils in these wetlands and the impacts increase as *Typha* x *glauca* stands age. Interestingly, *Typha* x *glauca* stand age did not appear to affect denitrification rates and quality as compared to uninvaded wetlands. Therefore, this critical ecosystem function of denitrification appears to remain intact even in the wetlands invaded by *Typha* x *glauca* for decades. We recommend that managers concerned with preserving wetland biodiversity should focus restoration activities on wetlands with newly established (< 11 years) *Typha* x *glauca* stands.

International Implications
If applicable to your report.

NONE

Media Coverage
This includes radio, TV, newspaper, and magazine coverage. Please send copies of clippings if possible.

NONE

Partnerships with other institutions/individuals initiated or continued by your project
This includes related projects with other institutions or individuals resulting from this Sea Grant-sponsored research.

Chicago Botanic Garden, Oregon State University, College of the Siskiyous

Publications (*if applicable*)
This includes journal publications (submit full reference and spell out journal title), reports, papers presented at conferences, poster presentation prepared by project staff and specifically resulting from Sea Grant-funded research during the project. Please submit a reprint of all publications to the IL-IN Sea Grant Office as they become available. Illinois-Indiana Sea Grant Program support should be acknowledged in all resulting publications and presentations.

Mitchell, M.E., S.C. Lishawa, N.C. Tuchman. *In prep* Ecological impacts of the invasive

species *Typha* x *glauca* after fifty years of establishment in Great Lakes coastal wetlands. Biological Invasions.

Lishawa, S.C., D.J. Treering, L. Vail, O. McKenna, D. Miceli, N.C. Tuchman. *In prep* Reconstructing the invasion history of a dominant wetland invasive plant species using historical aerial photography and pollen core analyses: applications for invasion ecology research. Biological Invasions.

McKenna, O., D. Treering, D. Miceli, L. Vail, S. Lishawa, and N.C. Tuchman. 2010. Reconstructing the history of emergent wetland plant invasions using aerial photo interpretation. Joint annual meeting of the North American Benthological Society and the American Society of Limnology and Oceanography, Santa Fe, NM.

Mitchell, M.E., P. Geddes, D. Larkin, S. Lishawa, D. Treering and N.C. Tuchman. 2010. Constructing a Timeline of *Typha* x *glauca* Invasion: Ecological Impacts after more than fifty years of invasion in Great Lakes coastal wetlands. Joint annual meeting of the North American Benthological Society and the American Society of Limnology and Oceanography, Santa Fe, NM.

Owen McKenna, Dr. N. Tuchman, S. Lishawa, D. Treering. February 2010. Analyzing the effects of invasive *Typha* x *glauca* on Great Lakes wetlands using aerial photo interpretation and in situ research methods. Poster Presentation at Loyola University Chicago Undergraduate Research Symposium. Chicago, IL February 25, 2010.

Owen McKenna, Dr. N. Tuchman, S. Lishawa, D. Treering. Effects of invasive *Typha* x *glauca* on wetland ecosystem characteristics. Poster Presentation at Loyola University Chicago Biology Department Undergraduate Research Symposium. Chicago, IL December 5, 2009.

Tuchman, N. C., P. Geddes, D. Larkin , K. Jankowski, M. Freyman, and L. Vail. 2009. *Typha* x *glauca*: An ecological engineer in Great Lakes coastal marshes? Symposium Topic: Genetics and Ecology of Cattail Invasions: Implications for Wetland Management. Society for Wetland Scientists, Madison, WI (Oral presentation by first author).

Mark E. Mitchell, Pamela Geddes, Daniel Larkin, and Nancy C. Tuchman. *Typha x glauca* invasion in wetlands of the Great Lakes region: Are impacts time-dependent? Oral presentation at the North American Benthological Society Meeting, Grand Rapids, MI, May 17-22 2009.

Mark E. Mitchell, Pamela Geddes, Daniel Larkin, and Nancy C. Tuchman. *Typha x glauca* invasion in wetlands of the Great Lakes region: Are impacts time-dependent? Poster presentation at the Frontiers in Life Sciences Symposium, Loyola University Chicago, Chicago, IL, April 17 2009.

Geddes, P. Invasive species and their effects on ecosystems. Invited seminar. Northeastern Illinois University, Chicago, IL. January 2009.

Undergraduate/Graduate Names and degree
Include the name of all undergraduate and graduate students supported by this grant and the degree pursued/earned. Theses or dissertations should be clearly identified as such, with author, title, degree, campus, and date.

-Mitchell, Mark - graduate student (MS in Biology). Thesis proposal title: Time-dependent effects of cattail (*Typha x glauca*) invasion on denitrification in Great Lakes area wetlands

-McKenna, Owen – undergraduate (BS in Biology; Loyola University Chicago)

-Applebaum, Eric – undergraduate (BS in Biology; Loyola University Chicago)

-Olszewski, Michal – undergraduate (BS in Biology; Loyola University Chicago)

-Miceli, David – BS in Biology (2009); Loyola University Chicago.

Related Projects
This includes grants from other funding agencies that resulted, as least in part, from this Sea-Grant sponsored research (i.e., leveraged funds). Please include the title of the project, funding agency, amount of new funding, and years of award.

-National Science Foundation (Division of Environmental Biology). "Collaborative Research: Fate of plant-derived carbon in freshwater wetlands undergoing Typha invasion: Ramifications for carbon accumulation and sequestration." P.I. D. Larkin, Co-PIs N.C. Tuchman, K.Kuehn, and P. Geddes. $972,311 requested for 3 years.

-US Environmental Protection Agency (Great Lakes Research Initiative Program). "A Sustainable Approach to Restoring Wetland Biodiversity." P.I. N.C. Tuchman, Co-PIs D. Albert and S. Lishawa. $800,000 requested for 3 years.

-Monks, Andrew. Effect of invasive *Typha* x *glauca* on denitrification potential and quality in Cheboygan Marsh, Northern Michigan. National Science Foundation, Research Experience for Undergraduates program. University of Michigan Biological Station. $6500 Awarded (Summer 2009)

-Olszewski, Michal. Effects of invasive plant species on wetland denitrification and greenhouse gas emissions. Carbon Scholars Program, Loyola University Chicago, $7500 Awarded (Fall 2008-Spring 2010)

-McKenna, Owen. Invasive plant species and wetland denitrification rates: Effects of water level and time since invasion. Mulcahy Scholars Program, Loyola University Chicago, $2000; (Fall 2009-Spring 2010)

Awards and Honors
Please list all awards and honors received within the time period covered by this annual report.

NONE

Patents/Licenses
List any patents or patent licenses that have resulted from this project.

NONE

Graphs, figures and/or photos
All accompanying visual aids should be embedded in your document. If you wish to send a high-res image file, you may need to email separately or send on a CD if size is a limiting factor.

Please identify which project the graphs or photos belong with and where they should be located in your report.
Please recognize that we may wish to include your photographs in our publications with the appropriate credits.

Questions or Problems?
If you need additional information, answers, or have questions concerning our reporting and grant requirements, please contact John Epifanio at 217-244-6916 or **epifanio@illinois.edu.**

References

Angeloni, N.L., K.J. Jankowski, N.C. Tuchman, and J.J. Kelly. 2006. Effects of an invasive cattail species (*Typha x glauca*) on sediment nitrogen and microbial community composition in a freshwater wetland. Federation of European Microbiological Societies Microbiology Letters 263: 86-92.

Boers, A.M., R.L.D. Veltman, and J.B. Zedler. 2007. Typha x glauca dominance and extended hydroperiod constrain restoration of wetland diversity. Ecological Engineering 29: 232-244.

Ehrenfeld, J.G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6: 503-523.

Jankowski, K.J. 2006. The effects of an invasive cattail (Typha x glauca) on nitrogen cycling in a Great Lakes coastal marsh. Loyola University Chicago.

Mason, C.F. and R.J. Bryant. 1975. Production, nutrient content and decomposition of *Phragmites communis* Trin. and *Typha angustifolia L.* The journal of Ecology 63: 71-95.

Rooth, J.E., J.C. Stevenson, and J.C. Cornwell. 2003. Increased sediment accretion rates following invasion by *Phragmites australis*: the role of litter. Estuaries 26: 475-483.

Tuchman, N.C., P. Geddes, R. Wildova, K.J. Jankowski, and D. Goldberg. 2009. Patterns of environmental change associated with *Typha x glauca* invasion in a Great Lakes coastal wetland. Wetlands 29: 964-975.

Weinstein, M.P., and J.H. Balletto. 1999. Does the common reed, *Phragmites australis*, affect essential fish habitat. Estuaries 22: 793-802.